

UNCLASSIFIED

AD 296 377

*Reproduced
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**



UNCLASSIFIED

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

63-2-4

296377

296377

CATINORE BY ASTIA

AS ALL 100



FINAL REPORT

PRODUCTION ENGINEERING MEASURE TUBE TYPES 7801 AND 6884

1 JULY 1960 THROUGH 31 DECEMBER 1962

CONTRACT DA 36-039-SC 85947
ORDER NO. 8220-PP-60-81-81

PLACED BY
UNITED STATES ARMY
ELECTRONICS MATERIEL AGENCY
PHILADELPHIA, PENNSYLVANIA

ELECTRON TUBE DIVISION
RADIO CORPORATION OF AMERICA
INDUSTRIAL TUBE PRODUCTS
LANCASTER, PENNSYLVANIA

FINAL REPORT

PRODUCTION ENGINEERING MEASURE
TUBE TYPES 7801 AND 6884

1 JULY 1960 THROUGH 31 DECEMBER 1962

**OBJECT OF STUDY: A PRODUCTION ENGINEERING MEASURE IN ACCORDANCE
WITH STEP I AND STEP II OF SIGNAL CORPS INDUSTRIAL PREPAREDNESS
PROCUREMENT REQUIREMENTS NO. 15 FOR ELECTRON TUBE TYPES 7801
AND 6884 CONSISTING OF THE FOLLOWING TASKS:**

- 1. FEASIBILITY STUDIES OF SPECIFIED PRODUCTION PROCESSING AREAS.**
- 2. PILOT RUN OF 200 TUBES TO DEMONSTRATE 100 PER MONTH CAPACITY.**
- 3. REPORTS IN ACCORDANCE WITH PARAGRAPH 3.8 OF SCIPPR NO. 15
AS SPECIFIED IN THE CONTRACT.**

CONTRACT DA 36-039-SC 85947
ORDER NO. 8220-PP-60-81-81

PREPARED BY: BEN SHEREN
PROJECT ADMINSTRATOR



ELECTRON TUBE DIVISION
RADIO CORPORATION OF AMERICA
INDUSTRIAL TUBE PRODUCTS
LANCASTER, PENNSYLVANIA

FINAL REPORT
PRODUCTION ENGINEERING MEASURE
TUBE TYPES 7801 - 8384 and 6884

TABLE OF CONTENTS

<u>Section</u>	<u>Description</u>	<u>Page</u>
I	PURPOSE.	1
I	Manufacturing Capability Established	1
	A. Electrode Spacing Techniques Improved	1
	B. Pilot Line Facilities Designed and Provided	1
	C. Life Test Equipment Designed and Built	1
	D. Test Equipment Approved and Design Approve Tests Conducted	1
II	Feasibility Studies Completed.	1
	A. Brazing Techniques	1
	B. Heater Design Improvement	1
	C. Mickel Thickness Measurement	1
	D. Molybdenum Thickness Measurement	1
	E. Electrical Discharge Machine Stability	1
	F. Broach Fabrication	1
	G. Grid and Screen Cylinder Revision	1
	H. Improve Parts Fabrication Methods.	1
	I. High Energy Rate Forming of Metal Parts	2
	K. Ultra-high Vacuum Application	2
III	Factory Production Implemented	2
	A. Factory Set-up and Personnel Trained	2
	B. Preproduction Run Tube Type 7801	2
	C. Pilot Run Tube Type 7801	2
	D. Preproduction Run Tube Type 8384	2
	E. Pilot Run Tube Type 8384	2
IV	Reports Prepared and Submitted.	2
	A. Monthly Narrative Reports	2
	B. Quarterly Reports	2
	C. Step II Reports	2
	D. Final Report	2
II	ABSTRACTS	3
I	Establish Manufacturing Capability.	3
	A. Improve Electrode Spacing Techniques	3
	B. Design Pilot Line Facilities	3
	C. Design and Build Life Test Equipment	3
	D. Design Approval Tests	3



TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Description</u>	<u>Page</u>
II	Feasibility Studies	4
	A. Brazing Techniques	4
	B. Heater Design Improvement	4
	C. Mickle Thickness Measurement	4
	D. Molybdenum Thickness Measurement	4
	E. Electrical Discharge Machine Stability	4
	F. Broach Fabrication	5
	G. Grid and Screen Cylinder Revision	5
	H. Improve Parts Fabrication Methods	5
	I. High Energy Rate Forming of Metal Parts	5
	K. Ultra-High Vacuum Application	5
III	NARRATIVE AND DATA	6
I	Establish Manufacturing Capability	6
	A. Improve Electrode Spacing Techniques	6
	B. Design Pilot Line Facilities	18
	C. Design and Build Life Test Equipment	21
	D. Design Approval Tests	21
II	Feasibility Studies	22
	A. Brazing Techniques	22
	B. Improve Heater Design	23
	C. Nickel Thickness Measurement	26
	D. Molybdenum Thickness Measurement	28
	E. Electrical Discharge Machine Stability	33
	F. Broach Fabrication	39
	G. Grid and Screen Cylinder Revision	41
	H. Improve Parts Fabrication Methods	41
	I. High Energy Rate Forming of Metal Parts	44
	K. Ultra-High Vacuum Application	46
III	Factory Production	50
IV	CONCLUSIONS	53
I	Establish Manufacturing Capability	53
II	Feasibility Studies	53
	A. Brazing Techniques	53
	B. Improve Heater Design	53
	C. Nickel Thickness Measurement	53
	D. Molybdenum Thickness Measurement	54
	E. Electrical Discharge Machine Stability	54



TABLE OF CONTENTS (Continued)

<u>Section</u>	<u>Description</u>	<u>Page</u>
	F. Broach Fabrication	54
	G. Grid and Screen Cylinder Revision	54
	H. Improve Parts Fabrication Methods.	54
	I. High Energy Rate Forming of Metal Parts	55
	K. Ultra-High Vacuum Application	55
III	Factory Production.	55
V	IDENTIFICATION OF TECHNICIANS	56



LIST OF ILLUSTRATIONS

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1	Cross-Section of Tube Type 7801	7
2	Distribution of Negative Grid Characteristic	10
3	Distribution of Positive Grid Characteristic	11
4	Distribution of Cutoff	12
5	Distribution of Cathode-Grid Capacitance.	13
6	Cross-Section of Grid-Screen Assembly with Spacing Wires in Place	15
7	Distribution of Eccentricity Measurements	17
8	Construction of Heater-Cathode Assembly for Tube Type 6884	25
9	Proposed Heater-Cathode Assembly for Tube Type 7801 Family.	25
10	Calibration Samples for Nickel Plating Thickness	27
11	Nickel Plating Thickness Measurements on Metallized Ceramics using the Dermatron Gauge Model D-2 and "A" Probe.	29
12	Correction Factor (K) Which Must Be Used to Obtain True Thickness Reading of Nickel Less Than 5/32 Wide Using Dermatron with "A" Probe	30
13	Dermatron Gauge and Probe	31
14	Taking a Reading with "D" Probe	31
15	Oscilloscope Presentation	36
16	Gain Characteristic Curves	38
17	Cross Section of Screen-Grid Assembly	40
18	Enlarged Section of Grid-Screen Assembly	40
19	Precision Boring Machine	43
20	Typical 6884 UHV Exhaust Curve	47
21	Typical UHV Exhaust Curve Using Latest Technique	49
22	Proposed Pumping Station for Exhaust Unit.	51
23	Schematic for "Dry" Vacuum Rotary Exhaust Unit	52



FINAL REPORT
PRODUCTION ENGINEERING MEASURES
TUBE TYPES 7801 - 8384 and 6884
SECTION I
PURPOSE

The objectives of this contract were to establish the manufacturing capability and acquire the facilities to produce a minimum of 100 tubes per month of Tube Types 7801 and 8384. In addition specified engineering studies were employed to improve producibility of these types and Type 6884 by advanced production techniques.

Reports and other information prepared as required by this contract were prepared for industrial mobilization and preparedness planning.

These objectives were accomplished in accordance with the following program outline (revised by Technical Action Request Number 1, approved 17 January 1962):

I. Manufacturing Capability Established

- A. Electrode Spacing Techniques Improved
- B. Pilot Line Facilities Designed and Provided
- C. Life Test Equipment Designed and Built
- D. Test Equipment Approved and Design Approval Tests Conducted

II. Feasibility Studies Completed

- A. Brazing Technique Improvement
- B. Heater Design Improvement
- C. Nickel Thickness Measurement
- D. Molybdenum Thickness Measurement
- E. Electrical Discharge Machine Stability
- F. Broach Fabrication
- G. Grid and Screen Cylinder Revision
- H. Improve Parts Fabrication Methods



30 JANUARY 1963

FINAL REPORT
DA-36-039-8C 85947

- I. High Energy Rate Forming of Metal Parts
- K. Ultra-high Vacuum Application

III. Factory Production Implemented

- A. Facilities Set Up and Personnel Trained
- B. Preproduction Run Tube Type 7801
- C. Pilot Run Tube Type 7801
- D. Preproduction Run Tube Type 8384
- E. Pilot Run Tube Type 8384

IV. Reports Prepared and Submitted

- A. Monthly Narrative Reports
- B. Quarterly Reports
- C. Step II Reports
- D. Final Report



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

SECTION II
ABSTRACTS

The statements below are abstracts of the indicated sections of the report.

I. Establish Manufacturing CapabilityA. Improve Electrode Spacing Techniques

The small size of components emphasized this problem which had been solved by laboratory skills.

1. Cathode-Grid Spacing

Precise spacing was obtained with spray application of lucite which was vaporized in the oven bake-out and pumped off during exhaust.

2. Grid-Screen Spacing

Precise spacing was achieved in production consisting of a metallic carbonate coating applied cataphoretically. After its use the carbonate was removed ultrasonically in a mild acid bath.

B. Design Pilot Line Facilities

Pilot line facilities have been established for production use and have a capability in excess of 100 units per month in all categories. Some sections have a capacity in excess of 1,000 units per month.

C. Design and Build Life Test Equipment

A two position, 1,000 megacycle, life test position has been successfully designed, built and employed to test tubes.

D. Design Approval Tests

In-Plant approval tests were conducted and approved under the supervision of Mr. S. Zucker, USAS MSA, 6 February 1962 for Tube Type 7801 and 17-18 October 1962 for Tube Type 8384.



II. Feasibility StudiesA. Brazing Techniques

Excellent brazing results were obtained by means of the Radiamatic Pyrometer. A semi-automatic, self-indexing furnace was designed to the layout stage. However, advances in the conventional State-of-the-Art offset the gains.

B. Heater Design Improvement

Mandrel modifications reduced filament breakage and insulation flaking. A monolithic heater-cathode assembly provided a more rugged construction. However its very rugged geometry did not justify the long processing and the geometry was not adopted for use. The improvement which became standard was the ceramic spool version.

C. Nickel Thickness Measurement

The Dermatron Gauge Model D-2 with "A" probe was adapted for use. Accurate calibration was established by comparison with metallurgical cross-sections of controlled plating on smooth metallizing. Calibration curves are included.

D. Molybdenum Thickness Measurement

The Dermatron gauge was employed for measuring the thickness of sintered molybdenum on ceramics. The method of calibration and instrument set-up was determined and found satisfactory. An easily reproducible secondary standard was developed

E. Electrical Discharge Machine Stability

The long term stability of the EDM was determined. The investigation undertaken is reviewed. Methods of increasing stability were determined and a maintenance procedure developed.



F. Broach Fabrication

The multiple problems of fabrication, reproducibility and tool life prompted a study to improve broach fabrication methods. A successful technique was developed using the projection grinder. Special grooving and improved tool material have appreciably increased broach life.

G. Grid and Screen Cylinder Revision

A review of the design to reduce the time required to cut the solid metal during EDM slotting resulted only in small savings which would not justify the redesign of tools.

H. Improve Parts Fabrication Methods

The design of the Tubes Type 7801 and 6884 depends greatly on parts fabrication. Close tolerances and high skills are required for fabrication. Tape controlled machines were found inadequate for the quantities required. The use of more advanced progressive dies and precision drawing were employed to improve this area of difficulty.

I. High Energy Rate Forming of Metal Parts

Because of the volume of high precision parts fabrication other methods were investigated. High-Energy Rate Forming (HERF) was investigated in all its facets. This approach was determined not feasible in view of the advances in conventional technique for parts formation.

K. Ultra-High Vacuum Application

Ultra-high vacuum techniques were investigated for comparison with conventional methods. Satisfactory results were obtained and tubes processed were submitted to the government for evaluation.



SECTION III

NARRATIVE AND DATA

In order to implement the objective of the program production capability and process improvements were obtained for tube types 7801 and 6884. Because of the nature of the separate designs the major design emphasis was directed toward the 7801. However, when an approach affected both types, the 6884 was used because of its availability.

I. Establish Manufacturing Capability

A. Improve Electrode Spacing Techniques

The small size of tube type 7801 emphasized the problems of employing conventional techniques to obtain alignment and spacing of (1) cathode and grid, and (2) grid and screen. These relationships determine the majority of the electrical characteristics of the tube. Processing techniques consistent with laboratory skills were employed to eliminate these problems. However, these techniques were not applicable to manufacturing procedures at Step II production rates. Recognition of this situation led to the inclusion of the following spacing studies and determined the methods necessary to establish the manufacturing capability. The critical requirements can be determined by a review of Figure 1.

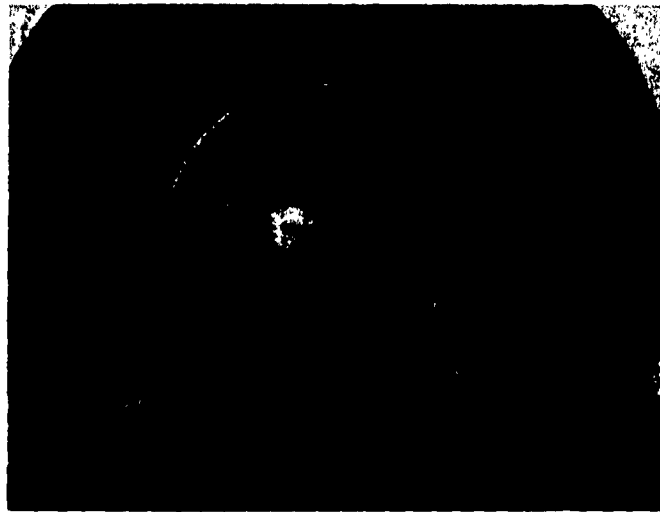
1. Cathode-Grid Spacing

The laboratory method of obtaining spacing employed a manual application of Lucite solution to the cathode assembly; overnight drying; and machining the solidified Lucite in a watchmaker's lathe to ± 0.0005 inch tolerance. This precise band of Lucite was used to maintain the cathode concentric within the grid cylinder during brazing of the external joint between the two assemblies. The Lucite vaporized in the oven bake-out and was pumped off during exhaust processing.



30 JANUARY 1963

FINAL REPORT
DA-36-039-SC 65947



Note satisfactory Cathode-grid relationship and eccentricity of screen with respect to grid.

FIGURE 1
CROSS-SECTION OF TUBE TYPE 7801



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

Investigation of various mechanical methods and the use of volatile materials in the form of tapes, machined parts and sprays led to the development of the present spray technique for applying the original Lucite material.

The spray application was relatively simple. The difficulty lay in developing a reproducible, controlled method of applying the shape and thickness in the limited location to insure the necessary electrode spacing. The breadth and depth of the spacer demanded a specific orientation of the spray gun; optimum spacing between nozzle and workpiece, and a very fine nozzle. The required uniformity necessitated a constant rotating speed of the workpiece; elimination of the trigger mechanism of the gun; improvement of the seals in the liquid passages of the system to prevent minute leaks; and determination of the optimum fluid composition.

A statistical analysis showing the favorable comparison with the laboratory method of the pertinent electrical characteristics was completed.

More than 100 tubes were assembled by the laboratory group using the sprayed Lucite method of obtaining cathode-grid concentricity. The experimental equipment with which the process was developed was moved into the manufacturing area for use in training factory personnel.

The production process developed satisfied the object of the study. In addition, there was a slight improvement in some of the pertinent electrical characteristics.

Analysis of test results showed the same percentage of rejections for extraneous causes between test lot and control. This indicated no



additional scrap factors introduced by the process change.

The characteristics most readily affected by cathode-grid eccentricity were negative grid voltage ($-E_{c1}$), positive grid voltage (E_{c1}), cutoff ($COEc$) and cathode-grid capacitance ($CK-G1$). These standard characteristic tests were included in the RCA Proposed Acceptance Specifications for Type 7801 dated 1 June 1961, which were prepared as required by Contract SC-78032.

The following graphs, Figures 2 through 5, show the distribution of 77 tested tubes made by the sprayed Lucite spacing technique compared with a control group of 58 tested tubes manufactured by the standard spacing method. This presentation was based on accepted procedures of statistical analysis and was intended to compare the average characteristic (\bar{X}) and the standard deviation (σ) of tubes produced by the two methods.

This graphic representation showed a significant difference in mean value of E_{c1} in favor of the test group. It was calculated at 5.74 volts, compared with 7.26 volts for the control. The $COEc$ characteristic also favored the new process in uniformity, since the standard deviation was reduced from 6.97 volts to 4.48. No significant differences in either mean value or dispersion were indicated by the plots of $-E_{c1}$ or $CK-G1$.



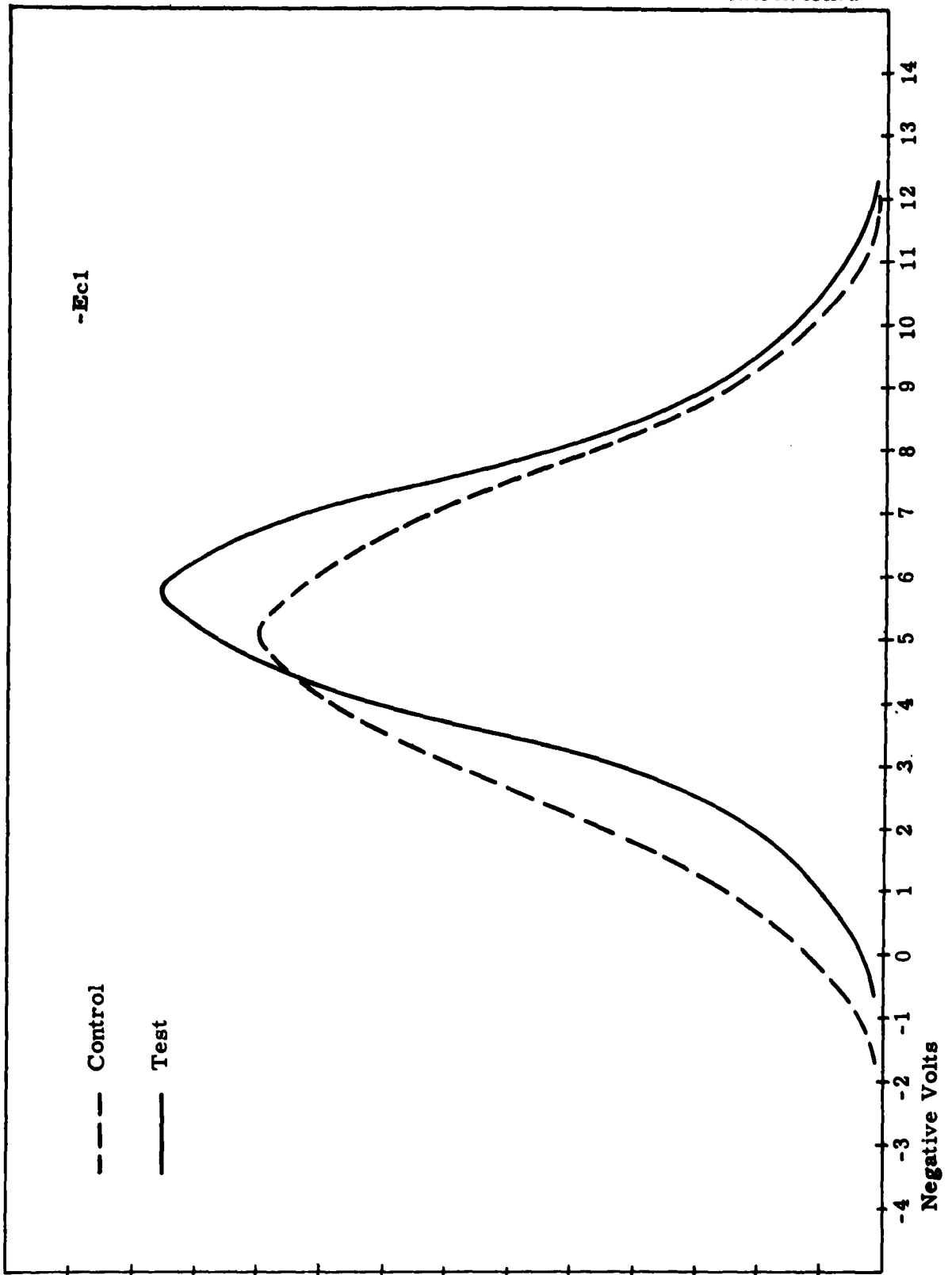


FIGURE 2
DISTRIBUTION OF NEGATIVE GRID CHARACTERISTIC



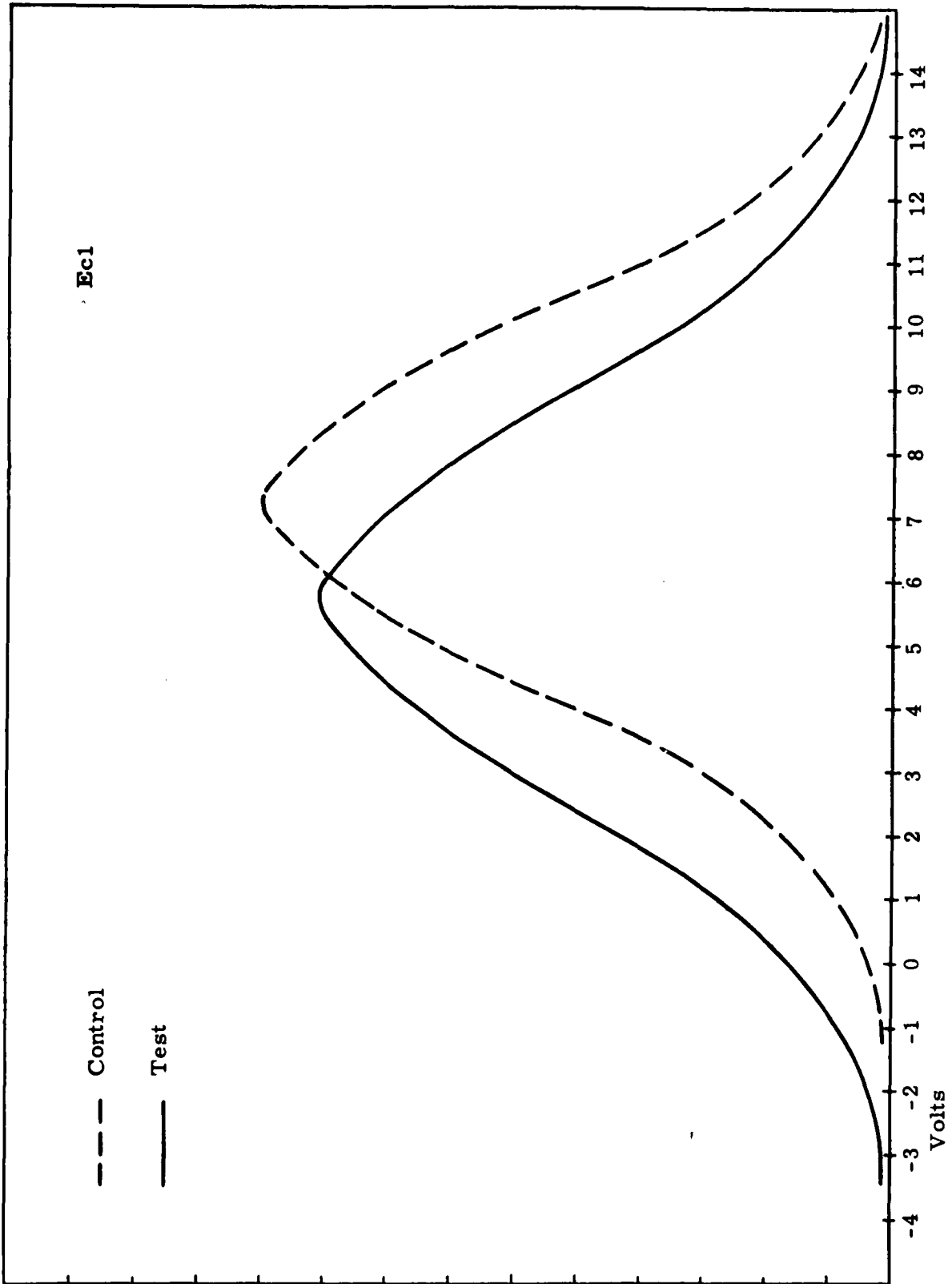


FIGURE 3
DISTRIBUTION OF POSITIVE GRID CHARACTERISTIC



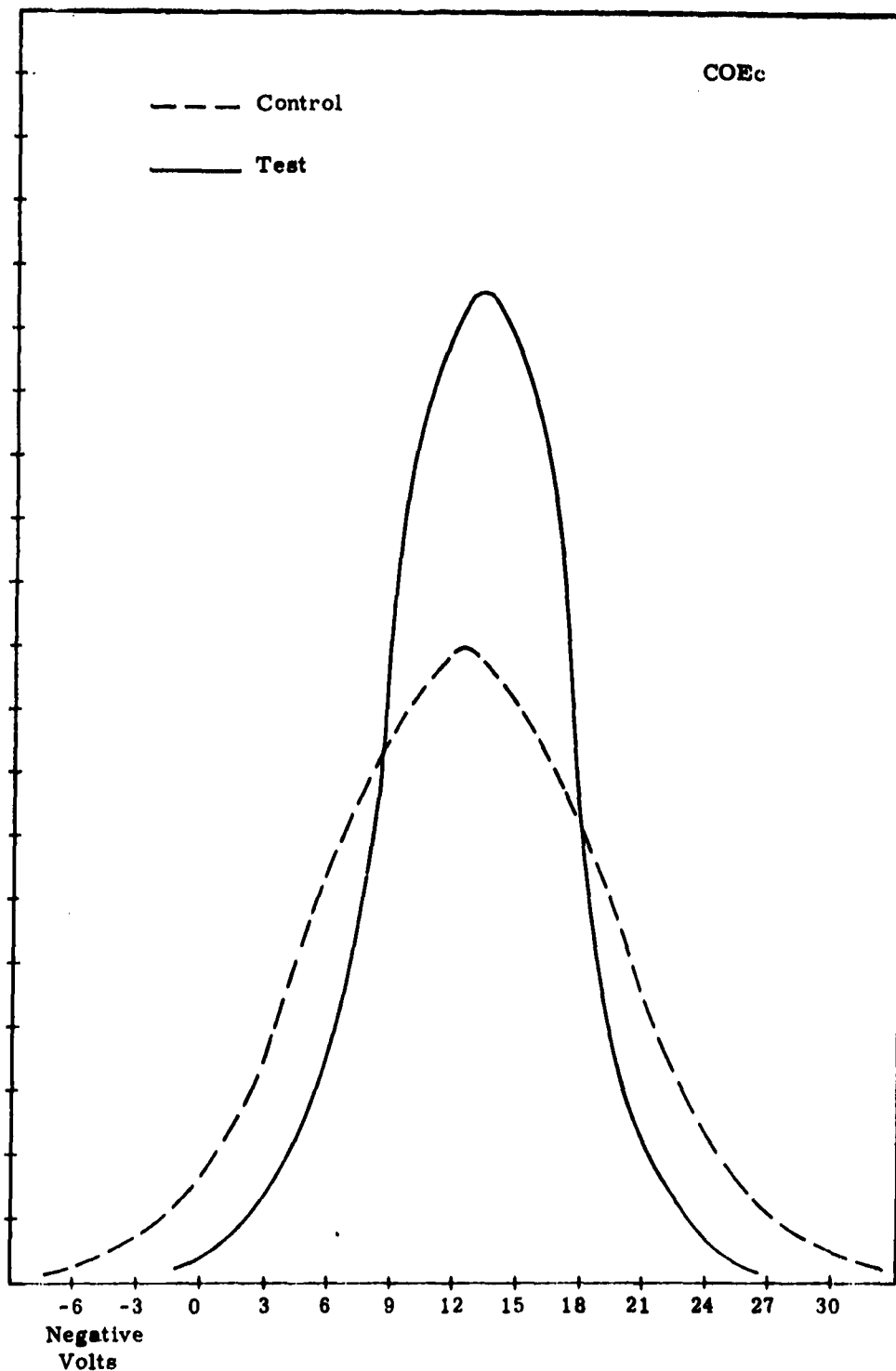


FIGURE 4
DISTRIBUTION OF CUTOFF



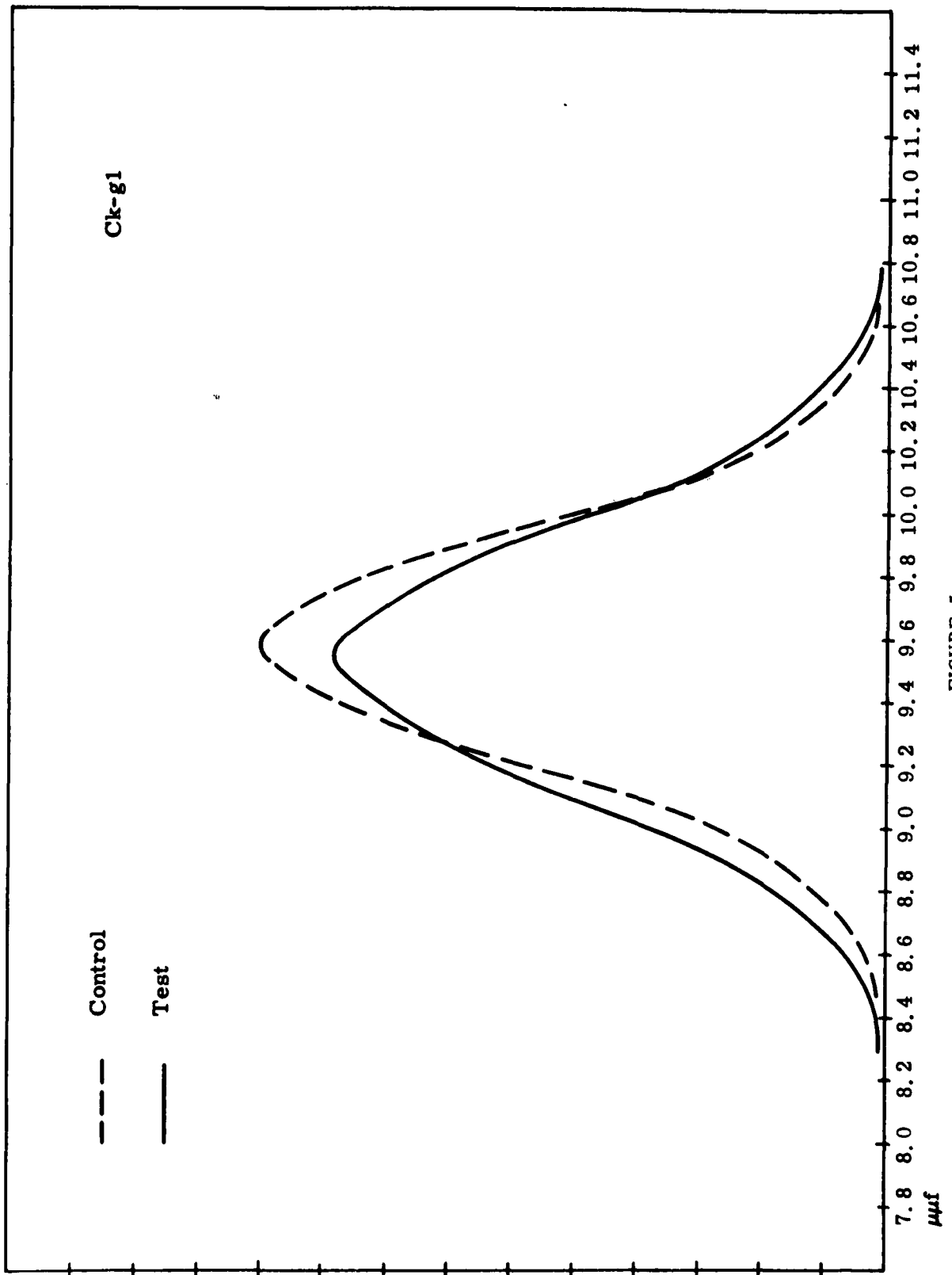


FIGURE 5
DISTRIBUTION OF CATHODE-GRID CAPACITANCE



This cathode-grid spacing process was incorporated into the manufacturing specifications for Tube Type 7801. It has deskilled the operation, increased the production rate, and improved the assembly yield.

2. Grid-Screen Spacing

The grid and screen cylinders were spaced for brazing in the laboratory by means of four steel ribbons of rectangular cross-section. These were cemented to the grid barrel with Lucite at 90° intervals, with the ribbon ends passing through slots machined in the grid flange for removal of the spacers after brazing. This technique was satisfactory for laboratory construction, however it was too slow for production and conducive to scrap because of the method of ribbon removal. Figure 6 shows a cross-section of a brazed grid-screen assembly with the spacing ribbons in place.

Of the various means investigated, much effort was devoted to the ribbed screen spacing medium. This approach was ambitious and known to be difficult. However, it had so much to offer that it was felt the rewards justified the effort. The ribs were incorporated in the part tooling and removed during electrical discharge slotting of the grids. Thus a tedious procedure could be eliminated and a critical operation performed in the course of other necessary operations at no extra effort or cost. The results were less than satisfactory. The study was abandoned when it became apparent that the ultimate accuracy was dependent on too many related operations and critical dimensions.

The method which was determined to have high production capability, consisted of a metallic carbonate coating applied cataphoretically. After serving its purpose as a spacer, the carbonate was removed ultrasonically in a mild organic acid bath.



30 JANUARY 1963

FINAL REPORT
DA-36-039-SC 85947

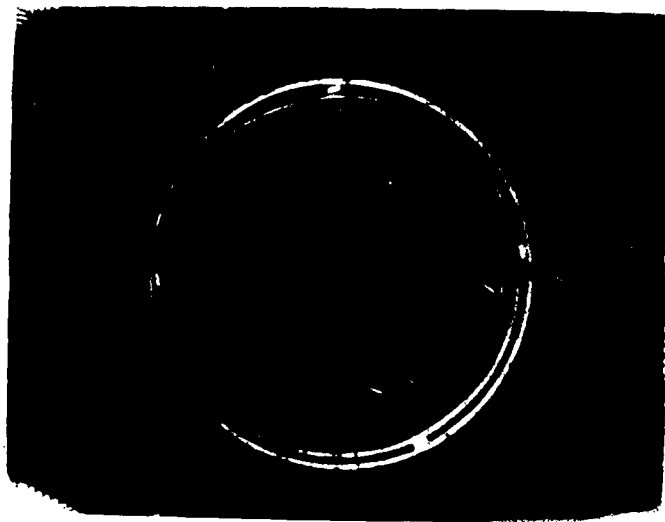


FIGURE 6
CROSS-SECTION OF GRID-SCREEN ASSEMBLY WITH SPACING WIRES IN PLACE



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

This phase of the study began with the use of magnesium hydroxide, applied manually. Some early tests were successful, but adherence and thickness were erratic. Various carbonates were tried, including the standard triple carbonate of barium, calcium and strontium used for emission coating of cathodes. This latter material worked satisfactorily, and a natural result was its application by cataphoresis. The coating is converted to oxides during the brazing operation. Both the oxides and the carbonates are then removed chemically.

Production tests were made using this spacing technique, and comparisons with the standard method were favorable. Data appearing in Figure 7 indicate a wider spread for coated grids, but there was less overall scrap, mostly because of the elimination of the ribbon removal operation.

Experience indicated that improvements could be expected, as in any new technique. Later investigations showed a phase change in the barium carbonate just above 800° Centigrade, which resulted in formation of a crystalline phase and a subsequent reduction in spacer thickness. Tests with strontium carbonate point to more stability of the spacer, and even greater coating uniformity. Distribution of a group of tubes made with a strontium carbonate spacer is also shown in Figure 7.

The carbonate coated grid method of obtaining grid-screen spacing has been determined to be satisfactory. Both triple carbonates and strontium carbonate are alternating in production tests with the ribbon spacer method. Triple carbonate spacing medium was used during the Tube Type 7801 pilot run on a portion of the product. These tubes are listed with their pertinent characteristics in Table I.



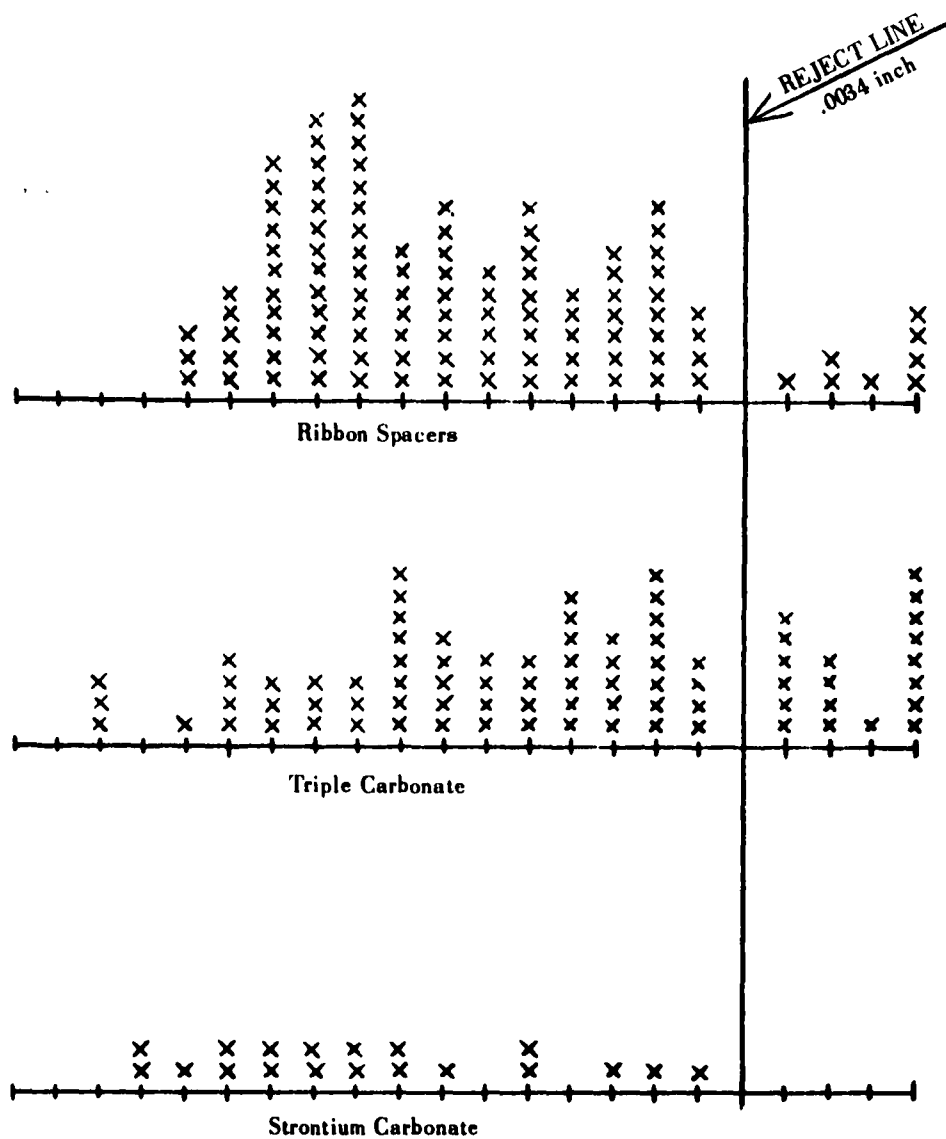


FIGURE 7
DISTRIBUTION OF ECCENTRICITY MEASUREMENTS
(Each cell is .0002 inch)



TABLE I
PERTINENT TUBE CHARACTERISTICS

Tube Number	PRI_s	(leakage) $-I_{c1}$	(gas) $-I_{c1}$	$-Ec_1$	$-IEc_1$	μ	$CoEc_1$
+NLB 32C	14.0	0	.1	6.0	5.2	31.3	12.6
+NLB 11C	12.5	1.2	.2	4.7	4.0	36.7	10.1
+NLB 44C	18.0	0	.2	6.1	5.2	27.8	13
+NLB 4C	12.2	.1	.1	4.6	3.8	31.3	10.6
+NLB 16C	15.0	.2	.1	5.2	4.5	36.7	11
+NLB 2C	12.2	0	.2	7	5.8	21	13.8
+NLB 55C	14.5	0	.1	3.8	3.2	41.6	8.5
+NLB 49C	11.5	0	.1	6.6	5.6	25	16.1
+NLB 31C	14.0	.7	.2	7.1	6.2	27.8	18.5
+NLB 22C	9.0	.8	.2	6.3	5.3	25	16.2
+NLB 10C	15.0	.3	.2	3.0	2.4	41.6	7.3
+NLB 58C	9.0	5.5	.5	4.6	3.8	31.3	11.4
+NLB 41C	17.5	.6	.1	5.9	4.9	25	12.7
+NLB 7C	10.0	0	.1	4.8	4.0	31.3	10.2
+NLB 67C	11.5	0	.2	4.1	3.3	31.3	10.1
+NLB 89C	19.2	.1	.1	4.4	3.8	41.6	11
+NLB 110C	7.3	0	.9	4.7	3.7	25	12
+NLB 92C	4.5	.1	2.4	6.7	5.5	21	16
+NLB 93C	8.0	.1	.1	8.4	7.2	21	19
+NLB 108C	12.2	.1	.3	5.4	4.6	31.3	13.5
+NLB 86C	4.5	1.5	.3	2.2	1.5	36.7	8.9

All parameters are within the requirements of the proposed MIL Specifications.



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

B. Design Pilot Line Facilities

Pilot line facilities have been established for production use having a manufacturing capability comfortably in excess of the program requirements.

Engineering drawings have been prepared for the special tools itemized below. These tools were designed to establish the manufacturing capability required.

<u>ITEM</u>	<u>RCA MODEL NO.</u>
Furnace, Brazing	L2780BE1
Gas Flow Gauge	L2706B1
Brazing Jig, Heater-Rod Assembly	L2829BM1
Heater Spool Welding Electrode	L2826AX1
Heater-Cathode Welding Electrode	L2826AW1
Heater-Cathode Brazing Jig	L2829BL1
Cathode Vac. Firing Plate	L754ES
Spray Mask	L2788M1
Sizing Jig	L2853H1
Drying Rack and Cabinet	L2856AF1
Firing Boat for Tube Parts	L2717AL1
Cleaning Tray, Grid-Screen Assembly	L2794F1
Firing Tray, Cathode	L2717AS1
Storage Tray, Cathode	L2856DW1
Storage Tray, Cathode-Heater Rod Assly.	L2856DX1
Storage Tray, Grid-Screen Assembly	L2856DZ1
Spacer Wire Assembly Jig	L2875DA1
Grid-Screen Assembly Fixture	L2875CW1
Grid-Screen Assembly Cleaning Basket	L2794E1
Grid-Screen Assembly Brazing Jig	L2829BN1



<u>ITEM</u>	<u>RCA MODEL NO.</u>
Heat Treating Furnace	L2780AG1
Gas Flow Gauge	L2706B1
Elox Power Supply	Commercial
Tool Holder and Fixture	L2705P1
Oil Filtration Unit	L2705K1
Electropolishing Unit, Single Pos.	L2864BP1
Brazing Jig	L2829BP1
Brazing Jig, Anode-Grid Assembly	L2829BR1
R. F. Brazing Unit	L772EF
Brazing Fixture	L2829BT1
Short & Continuity Tester	L2762C1
Tube Socket	L2742K1
Leak Detector, Two Position	L722SS-12
Leak Detector, Two Position	L722SS-12
Leak Detector, Two Position	L722SS-12
Activation Socket	L2702C1
Compression Head	L2702C2
Semi-Universal Aging Rack	L734FP1
Tube Socket Adapter	L766DD
Tube Socket	L2742K1
S. A. Adaptor	L732GJ
Tube Socket	L2742K1
S. A. Adaptor	L766CH
Tube Socket	L2742K1
Firing Boat	L2717F1
Power Tube Short Test Set	L762N
Safety Switch	L709H
Tube Socket	L2742K1
Gauge Concentricity	L2906BT1



<u>ITEM</u>	<u>RCA MODEL NO.</u>
Assembly Fixture	L2875DK1
Grid-Screen Concentricity Gauge	L2909CK1
Optical Comparator Fixture	L2725AX1
Screen Wire Measuring Device	L2725AU1
Filament Preheater	L2761B4
Tube Socket	L2742K1
Winding Machine	L2704E1
Socket Adaptor	L2762B1
Tube Socket	L2742K1
Cleaning Equipment	L2886AH1
Holder, Grid-Screen Assembly	L2856CX1
Cleaning Equipment	L2886AH1
Pneumatic Gauge, Inside Diameter	L2798HL, 2, 3
Pneumatic Gauge, 3 Circuit Squareness	L2798F1, 2, 3
Pneumatic Gauge, Wall Thickness	L2798G1, 2, 3
Short Pinch-Off Tool	L2702AP1

C. Design and Build Life Test Equipment

A two-position test set was designed and built for 1000 megacycle life test operation. Thirteen tubes were successfully life tested, including both Tube Types 7801 and 8384 in accordance with preproduction sample and pilot run requirements.

D. Design Approval Tests

Satisfactory in-plant design approval tests of tube type 7801 were conducted at the Lancaster plant 6 February 1962 under the direction of Mr. Simon Zucker, USAS MSA. Tubes were tested to the proposed military specification dated 14 November 1961 as revised by the Contracting Officer's letter of approval dated 9 January 1962.



Tube Type 8384 was also satisfactorily tested under Mr. Zucker's supervision at Lancaster, 17-18 October 1962. These tubes were tested in accordance with the proposed military specifications dated 30 September 1962.

II. FEASIBILITY STUDIES

A. Brazing Techniques

An investigation was started to develop the facilities for high volume brazing of tube assemblies at low scrap. Differential brazing employed in these tubes required very critical time-temperature control.

An existing production furnace was fitted with a total-radiation type pyrometer manufactured by the Minneapolis-Honeywell Company. This instrument, known as the Radiamatic Pyrometer, was thoroughly evaluated. Following a series of adjustments and modifications to the installation based on power tube engineering experience, the Radiamatic Pyrometer was demonstrated to be of dependable accuracy and repeatability. It was used on all production brazing operations for the subject tube types. Scrap reduction was credited to the use of this device, and brazing procedures became a controlled technique.

Because of the success of the Radiamatic Pyrometer, a high speed, self-indexing furnace was designed utilizing this instrument as the index control. The design incorporated a vertical lift into the brazing position and horizontal indexing into both preheat and cooling areas. This furnace was designed to provide a high speed brazing operation, with controlled purity atmosphere and minimum vibration movement. This design was carried to the layout stage. State-of-the-art advances relaxed some of the brazing requirements and expedited manual furnace brazing, so that a semi-automated facility could not compete on the basis of flexibility for any quantities.



B. Improve Heater Design

The original proposal included a study to improve the means of joining the two ends of the heater to their connecting parts. Environmental test evaluation of the tungsten heaters used in the 6884 and 7801 indicated the need for redesign of the heater-cathode assembly rather than improvement of the joints.

Among the early contributions to improved heater reliability was an analysis of the heater helix which showed high stress at the heater leg. This design contributed to filament breakage and flaking of the insulation coating in the region of the "knee". A mandrel modification was proposed which altered the leg shape and reduced in-process failures. Impact tests from 200 to 500 G were applied to four improved tubes and four controls. Three out of four test tubes passed, against three failures in four control tubes. The survivors of the modified heaters failed at 20 G vibration tests between 100 - 200 cps, while the standard design did not withstand 5 G in this range.

Several approaches to improved heaters were investigated. The most promising investigations proved to be the monolithic, or nickel-embedded heater, and the ceramic spool version.

The monolithic construction provided a rugged heater-cathode assembly for Tube Type 6884. Tubes prepared with this refinement passed extended life tests, and both intermittent and overloaded filament tests. However, this tube requires high-temperature filament processing of long duration for stabilization of an electrical characteristic not common to most tubes. The heater temperature exceeds any to which the filament is subjected during normal processing or operation, and the monolithic heater is marginal under this limited-processing condition. The design was adapted for the 7801 family, but could not be justified for economic considerations.



The ceramic spool heater was tried in many variations before the problem of the high temperature joint between heater leg and support rod was resolved. When the critical brazed joint was replaced by a welded nickel construction the breakthrough became evident. The improved assembly used a nickel flange and eyelet welded to the support rod, which in turn was brazed to the metallized end of the ceramic spool, sandwiching the heater in the joint. A similar construction was used at the opposite end, providing for a second nickel-to-nickel weld between the cathode and lower heater flange. The heater-cathode assembly is shown in Figure 8.

This construction features the following improvements over the standard assembly:

- (1) Eliminates heater legs, which are usually the major point of breakage;
- (2) Contains no tungsten welds, avoiding heater recrystallization and embrittlement;
- (3) Ceramic instead of metal spool for helix support eliminates the prevalent heater-to-spool short if insulation coating flakes off;
- (4) Improves fabrication because of simpler parts, lower processing scrap, more rapid assembly and reduced field breakage.

Tubes containing the new assembly passed all testing requirements. These included regular factory and design characteristics tests, heater cycling and overload tests, standby life tests, dynamic life tests and vibration tests.

The final production run and detailing of specifications is in progress, preparatory to standardization of the 6884.

The improvements realized on the Tube Type 6884 were also investigated for the 7801 family. The proposed design shown in Figure 9 was fabricated and cycled successfully as heater-cathode assemblies. Preliminary testing and Type 6884 experience predict greater ruggedization and assembly advantages.



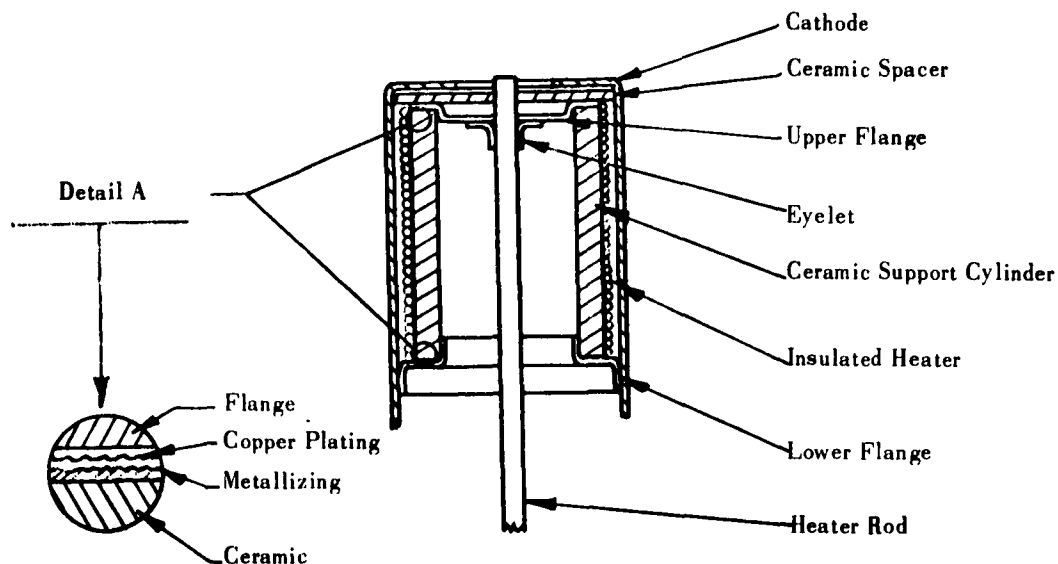


FIGURE 8
CONSTRUCTION OF HEATER-CATHODE ASSEMBLY FOR
TUBE TYPE 6884

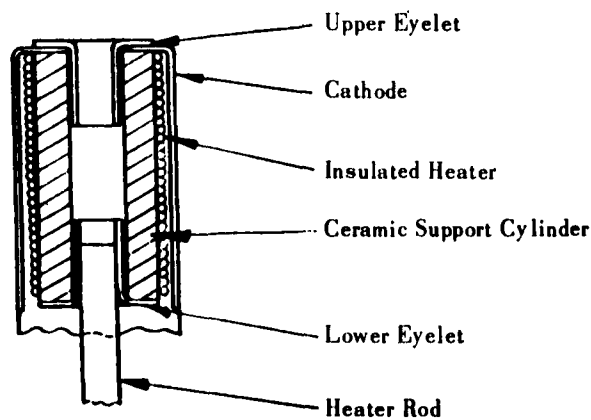


FIGURE 9
PROPOSED HEATER-CATHODE ASSEMBLY FOR
TUBE TYPE 7801 FAMILY



C. Nickel Thickness Measurement

A non-destructive control of nickel plating thickness on metallized ceramics was needed to insure good joint quality in the production of ceramic-metal seals.

The metallizing process consists of the application of a thin layer of molybdenum to a ceramic part in the area of the brazed joint, usually as part of the tube envelope. A molybdenum solution is applied to the seal area by means of screen printing, then sintered at high temperature to bond the metal to the ceramic. The molybdenum layer is finally nickel plated to insure wetting the entire surface by the brazing material. For reliable, vacuum-tight joints the plating thickness must fall within the specified range of 0.0001 inch to 0.0003 inch.

A survey of measuring techniques and commercially available equipment was made and tests conducted on those which showed promise. The most satisfactory was the Dermatron gauge, Model D-2, made by Unit Process Assemblies, Inc. When fitted with an "A" probe, this device was sensitive to thin films of nickel, virtually independent of the molybdenum base. The balance of the investigation covered the calibration of the unit and the determination of a conversion chart to interpret gauge readings in terms of nickel thickness.

Early attempts to calibrate with production parts were unreliable because of the comparative roughness of the metallizing. Efforts were made to obtain a range of thin nickel measurements by micrometer, by metallographic section, photographic enlargement, and statistical methods. The technique developed employed a self-levelling molybdenum solution used with very smooth ceramics. These metallized parts were plated in pairs in varying thickness from 0.00005 inch to 0.0005 inch. After the Dermatron gauge verified the matched thicknesses, one of each pair was sectioned and measured in a metallurgical microscope to determine exact thickness. The remaining samples were retained for final calibration. Figure 10 shows sections of calibration samples at high magnification.



30 JANUARY 1963

FINAL REPORT
DA-36-839-8C 88947



.00014 inch



.00006 inch



.00019 inch

FIGURE 10

CALIBRATION SAMPLES FOR NICKEL PLATING THICKNESS



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

The Dermatron gauge was adjusted according to the instructions set forth for Case I in the instruction book using alternate set up adjustment procedure described under Appendix B of the instructions. The probe was then applied to a piece of rolled nickel 0.0005 inch thick in order to adjust the gauge for zero reference reading on the meters, then after removing the sample the instrument was adjusted for full scale meter reading. The 0.0005 inch nickel was selected for zero reading because it placed the range of plated nickel calibration samples at approximately the middle of the scale on the meter. Figure 11 shows the resulting conversion curve of thickness versus meter reading on the Dermatron gauge.

A correction factor curve is shown in Figure 12. This correction must be applied when measuring nickel plating less than 0.156 inch wide, because of limitations of the "A" probe.

D. Molybdenum Thickness Measurement.

A high volume method of inspecting molybdenum thickness on ceramics was required as a portion of the program.

The Dermatron gauge was found to be a practical means of obtaining sintered molybdenum thickness measurements. However, the use of a "D" probe was necessary. The Dermatron gauge and a photograph of it in use are shown in Figures 13 and 14. Initially the gauge was set up against a standard 0.001 inch molybdenum sheet to establish a scale range. During the investigation it was determined that accurate correlation existed between the Dermatron readings and metallizing depth.

In order to calibrate the instrument and establish a conversion chart, four ground ceramic parts were coated successively with one to four layers of molybdenum solution and sintered. The parts were then care-



PRELIMINARY GAUGE ADJUSTMENTS

1. Set "Operate" switch to pos. 1
2. Adjust "Balance" control for zero with probe applied to .0005 thick nickel sheet (zero standard)
3. Adjust "sensitivity" control for full scale (100) with nothing under the probe.

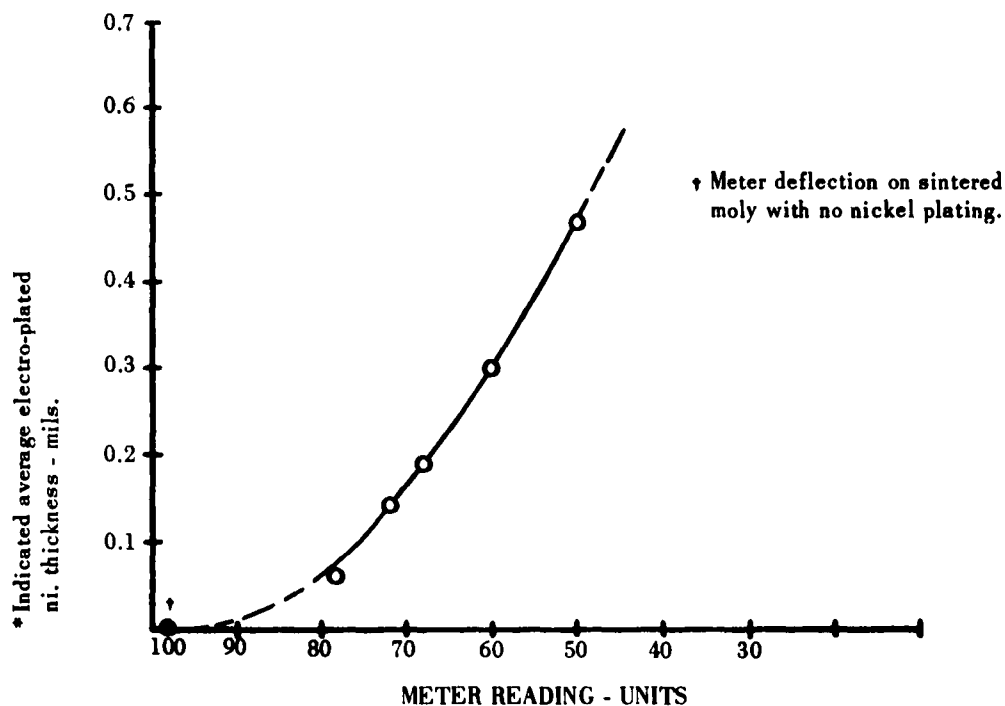


FIGURE 11
NICKEL PLATING THICKNESS MEASUREMENTS ON METALLIZED CERAMICS USING
THE DERMITRON GAUGE MODEL D-2 AND "A" PROBE

* It will be noted that the 0.0005" electro-plated nickel does not cause the meter to read zero as the nickel sheet does. This is believed to be due to physical differences such as density, permeability, and surface uniformity in the plated samples.



CORRECTION FACTOR (K) WHICH MUST BE USED TO OBTAIN
TRUE THICKNESS READING OF NICKEL LESS THAN 5/32 WIDE
USING DERMITRON WITH "A" PROBE.

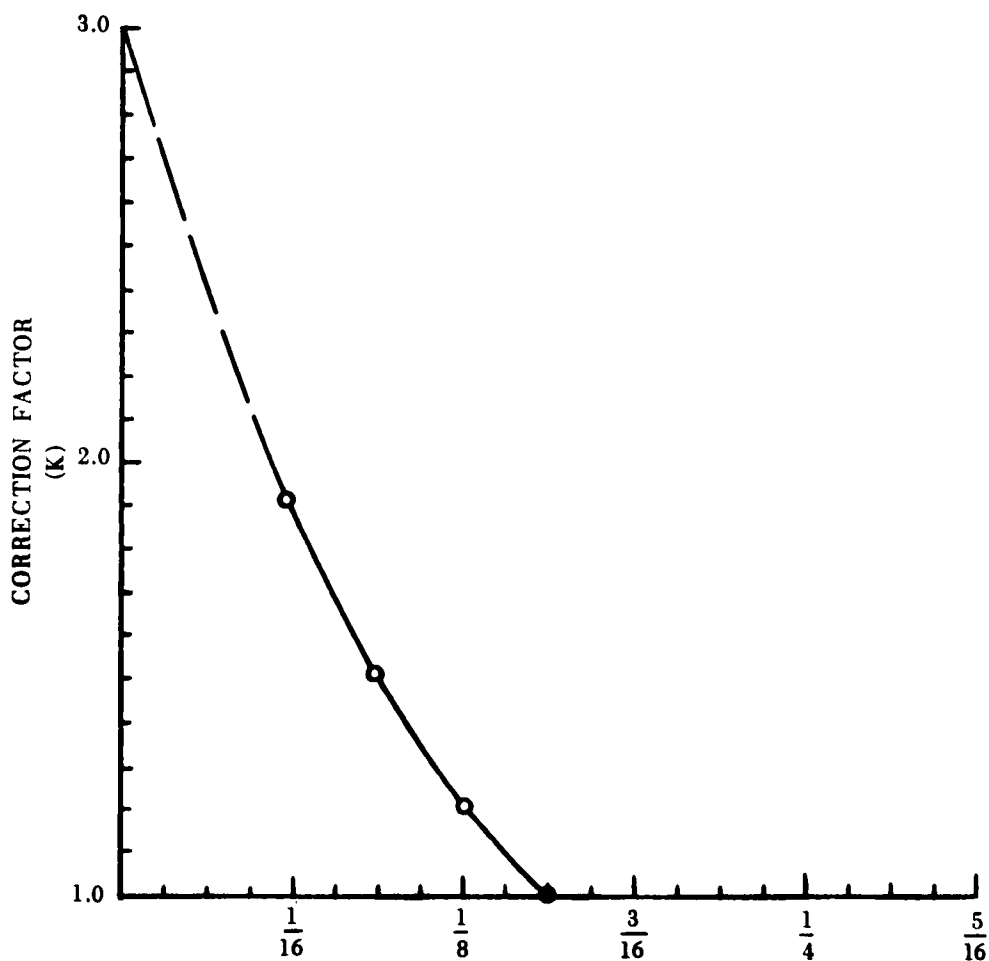


FIGURE 12



30 JANUARY 1963

FINAL REPORT
DA-36-039-SC 88947

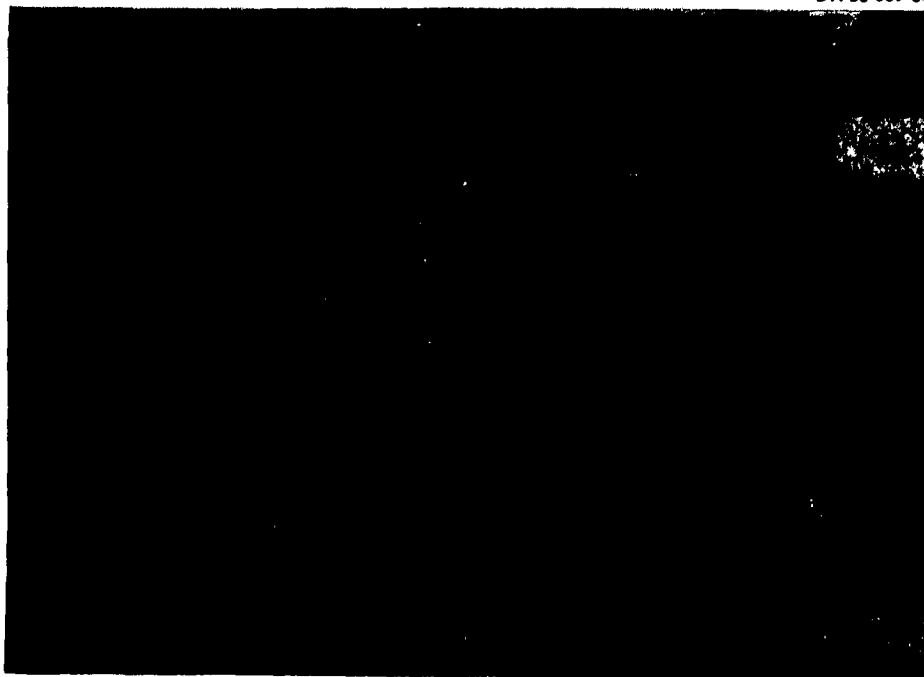


FIGURE 13
DERMITRON GAUGE AND PROBE

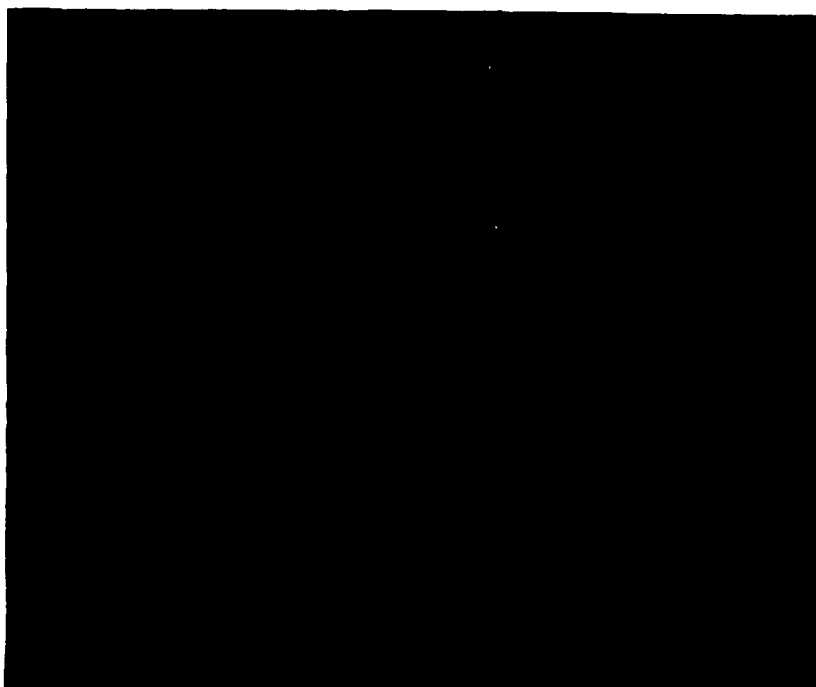


FIGURE 14
TAKING A READING WITH "D" PROBE



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

fully measured with a ball point micrometer at adjacent points on the coated and uncoated areas; the difference between adjacent readings was the metallized thickness.

The Dermatron gauge was set up according to the manufacturer's instruction manual, Case IV-A. The gauge was balanced at zero, then set for full scale by means of the sensitivity adjustment with the thickest sample under the probe. The samples of known thicknesses were then read and plotted, gauge reading versus thickness. This plot became the standard conversion chart.

Because of the need for repeated, daily use of the original coated ceramics and the difficulty of replacement, it was determined that readily reproducible calibration devices were needed. Taking advantage of the coupling principle on which the Dermatron performance is based, a heavy copper slab was placed under the probe and spaced from it by inserting progressive thicknesses of a dielectric material until the desired reading was observed. It was thus established that a copper sheet 0.0625 inch thick covered with 0.010 inch thick teflon layer simulated 0.0015 metallized molybdenum on ceramic, and 0.020 inch teflon corresponded to 0.00062 inch metallizing.

The calibration device stood the test of repeatability where the same instrument was used, but because of differences in Dermatron gauge characteristics separate calibration charts were required for each gauge.

In summary it may be stated that the Dermatron gauge is a reliable means of measuring molybdenum metallizing on ceramics in high volume production. In order to utilize this device it was necessary to establish a conversion curve for each instrument by means of metallized ceramics of known thickness. The calibration device described will be used to assure accurate instrumentation.



E. Electrical Discharge Machine Stability

The early history of electrical discharge machining (EDM) as a production process was marked by variations in cut, cutting rate, and quill hunting. In the absence of satisfactory explanations for this behavior a program was proposed to investigate the aging of circuit components, as it affected repeatability of machine settings, and to study the control of the cutting spark to establish reliability.

The equipments used in EDM processing of grid-screen assemblies were the NPS-15 and NPS-30 Power Supplies and Elox Machines, made by the Elox Corporation of Michigan. An evaluation was made of each circuit employed as listed below:

- (1) Waveform Generator
- (2) Waveform Generator Power Supply
- (3) Cutting Power Supply
- (4) Pass Tube Circuit; and
- (5) Servo System.

After a review of the circuitry, measurements were made of the static voltages and dynamic waveshapes to determine the equipment characteristics. This information was tabulated and used as a reference standard for later repeat measurements.

To determine the stability of the supplies in a positive manner a program was set up to check the voltages and wave shapes every three months. The data obtained during the second series of these checks showed no changes which may have any effect on the frequency, duty cycle, or amplitude of the cutting wave shapes within the five per cent accuracy of reading an oscilloscope. During this period the machine did not appear completely stable, especially when cutting at the higher frequencies without adding additional capacity across the cutting gap. Therefore, an attempt was made to observe the dynamic cutting current wave shapes during cutting with the aid of storage oscilloscopes and other means.



Four series of voltage and wave shape readings were taken at three month intervals and the results were such that no significant change was noted. The accumulated machine time to 15 September 1962 which was the date of the last series of tests was:

NPS - 30	Laboratory	Run Time 2643 hrs. Cutting Time 1900 hrs.
NPS - 15	Laboratory*	Run Time 3545 hrs. Cutting Time 1738 hrs.
NPS - 15	Production	Run Time 6306 hrs. Cutting Time 3387 hrs.
NPS - 15	Production	Run Time 14280 hrs. Cutting Time 4369 hrs.

*This machine was used for production for a period of about three months.

From the very beginning of this study it was known that a capacitor of at least 0.2 μ f microfarad had to be placed in parallel across the cutting gap for reasonable stability during cutting. As experience was gained by working with the power supplies it was learned that for the best compromise between fineness of surface finish and satisfactory long time stability of the machine a capacitor of 0.5 μ f minimum must be used.

As a result of dynamic cutting current observations, it was established that the servo system was responsible for a large part of the instability that occurred in the machine. However, before full evaluation could be completed, assurance was necessary that other machine factors were in proper operation. Therefore, a trouble shooting procedure was developed for logically and quickly correcting situations when instability was encountered. This procedure follows:

If machine instability exists the following items must be checked for proper operation before the electronic portions of the machine can be evaluated:

1. Coolant Flow. Sufficient flow is required to remove the eroded material, but not so much so as to cause turbulence in the sparking region, or to cause the tool or work to vibrate. A flow rate of approximately two gallons per



- minute is required into the grid structure.
2. Mechanical linkage between the servo motor and quill. No more than two turns of servo motor backlash may be tolerated.
 3. The Servo down-feed control should be set so that the tool is not being forced into the work at a rate faster than the material can be removed.
 4. The mica (only mica is satisfactory for this application) capacitor across the gap should be checked or replaced with one known to be good. The capacitor should be $0.5 \mu f$ or greater for reasonable stability over long periods of time. Capacitors smaller than $0.2 \mu f$ have not produced long time stability even though they produced finer cuts. As the mechanism of the servo becomes worn and develops excessive play, larger capacitor values are required to reduce excessive hunting.

If all of the above items are satisfactory, a check of the electronic circuitry should be made with the machine turned on, the clutch disengaged, and the tool backed away from the work.

1. Put an oscilloscope and D. C. voltmeter on any control grid of the 6DQ5 drivers. The oscilloscope presentation should be as shown in Figure 15. The D. C. voltage should be a negative 50 volts \pm 20% depending on the "Tap" and "Rate" dial setting. If this is not the case, then there is some malfunction in the waveshape generator and conventional electronic trouble shooting techniques should be used to locate the trouble.
2. The oscilloscope and meter should be observed. The meter gap and a similar waveshape should be observed. The meter should read 60 to 80 volts (machine frame positive with respect to the tool holder). If this is not the case the output stage should be investigated for trouble, again using standard techniques.
3. A check of the rectifying diode should be made. Because a vacuum diode has higher inverse voltage ratings and is less apt to break



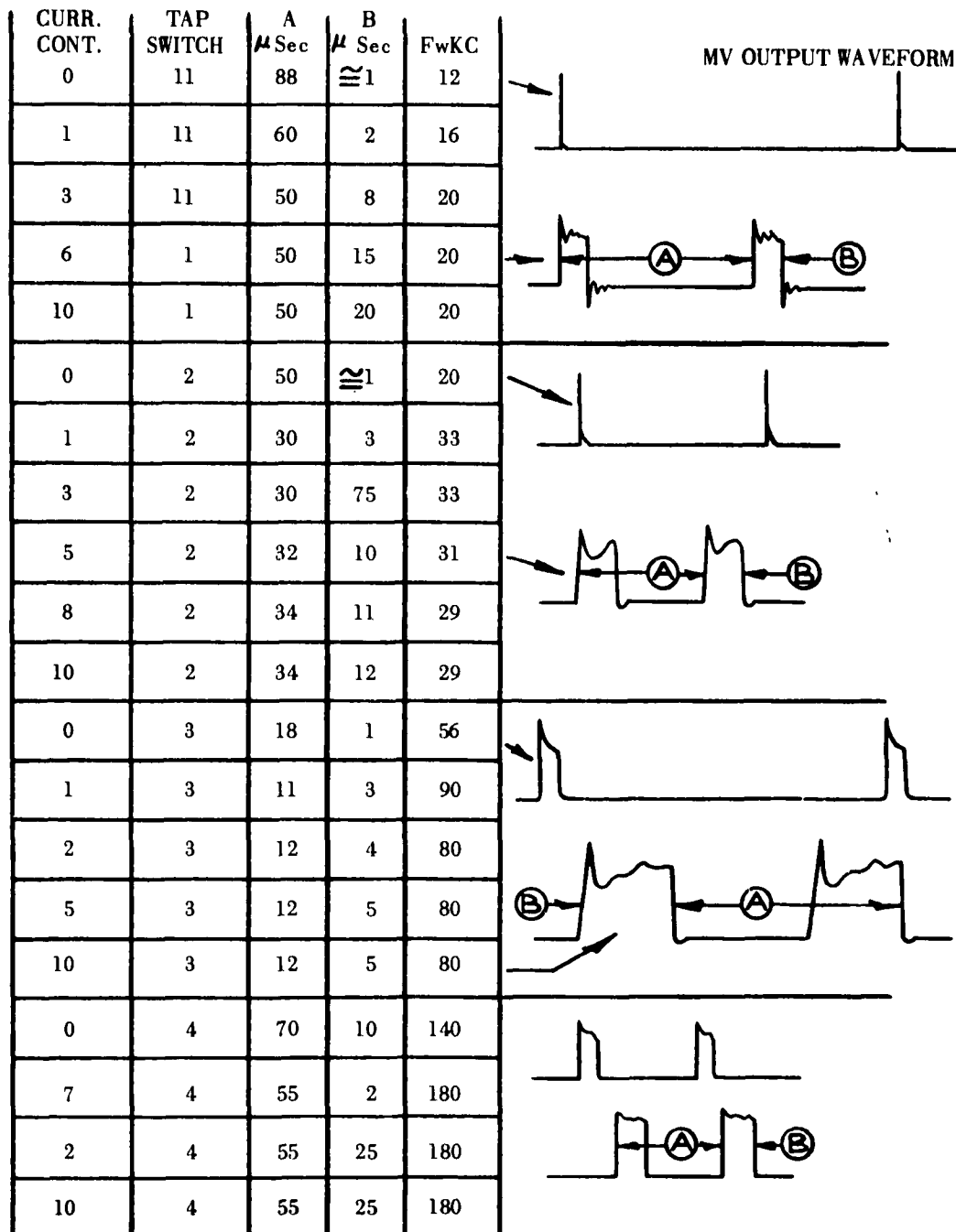


FIGURE 15
OSCILLOSCOPE PRESENTATION



down due to voltage transients, it is recommended that a 6X4 vacuum tube be used here instead of the solid state rectifier.

4. A check of the servo response should be made by plotting the input and output voltages of the transistor amplifier. Satisfactory curves are shown in Figure 16. If the curves taken are not similar to these curves, transistor replacement is advised. An increase in stability and reliability can be achieved by improving heat sink efficiency of the transistors in the servo-motor amplifier of the electrical discharge machines. The reduction of leakage current stabilizes operation.

The trouble shooting methods described above have been used on all four machines when required, resulted in improved stability of operation. They were used to make a final check of the servo response on the four machines.

The overall maintenance record of the four machines has been satisfactory and as the operators gained experience in their operation, fewer maintenance calls were received.

During the course of this study no major instability developed that could not be corrected using the maintenance techniques developed. It was noted, however, that different wire sizes were obtained from different machines with the same control settings. Although the individual minor differences between any two machines when evaluated by themselves seem to be insignificant, in accumulation their net effect is to cause the measurable differences in cutting results. Comparable wire sizes can be obtained from different machines by making minor deviations in control settings from machine to machine.

In general, the ELOX NPS-15 and NPS-30 Power Supplies are reliable and with available experience at RCA satisfactory results can be obtained.



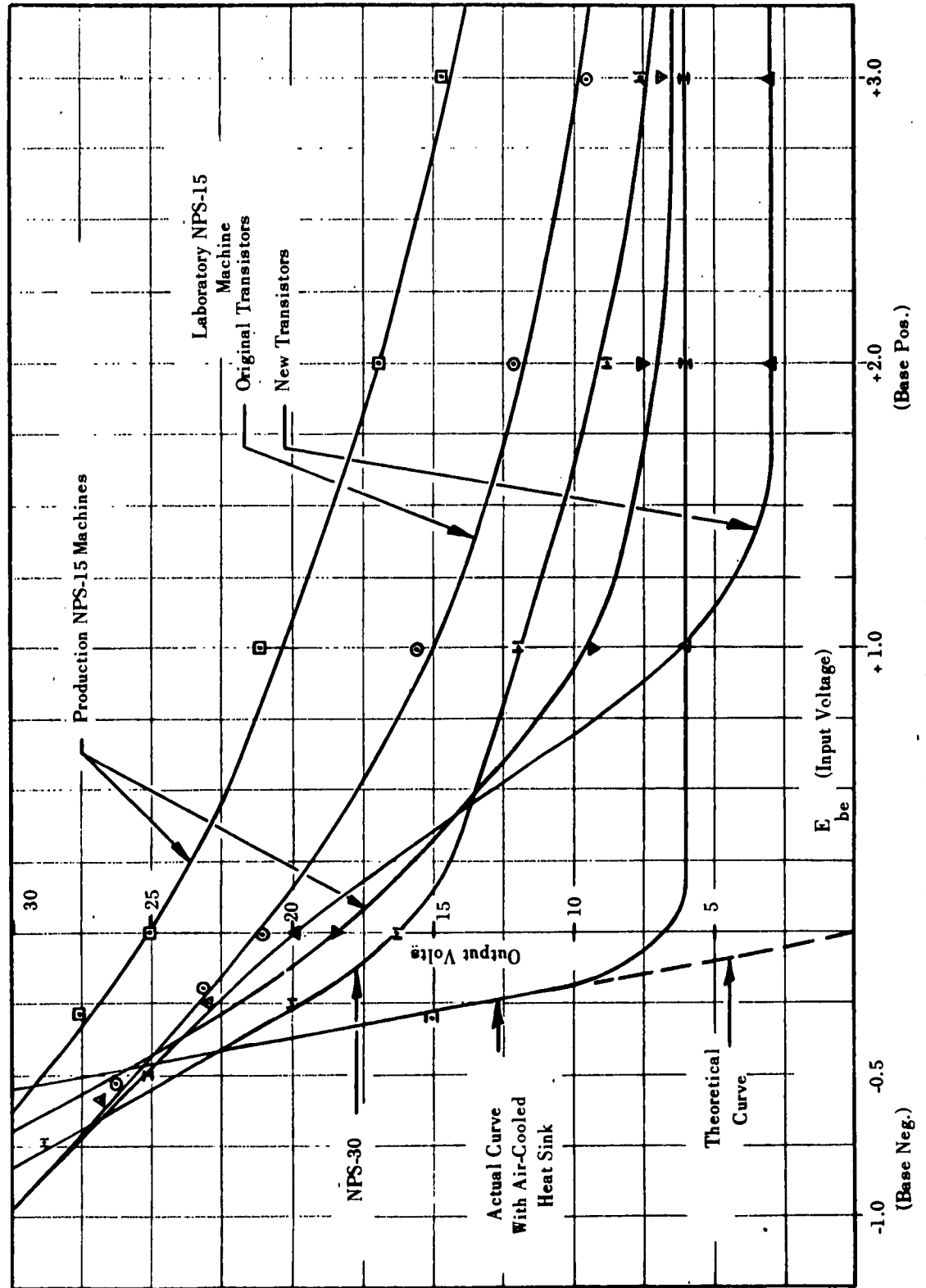


FIGURE 16 - GAIN CHARACTERISTIC CURVES



F. Broach Fabrication

The extremely accurate alignment of grid and screen required by the 6884 and 7801 tube families has been attained by the technique developed specifically for this tube concept. This technique consists of slotting a brazed assembly of two concentrically spaced cylinders by electrical discharge machining so as to form the grid and screen "wires" simultaneously. The electrode used in this operation must have a shape matching the desired configuration in reverse, and must be precisely reproducible. The electrode is expended in the fabrication of a single assembly. A new electrode of soft brass is broached for each assembly.

The electrodes are made by conventional broaching, so the basic problems of accuracy and reproducibility are transferred from the electrode to the broach. In the past, the broach was machined by highly experienced machinists, using a Norton grinder with a Griswold indexing head. The degree of difficulty may be assessed by studying Figure 17, which shows the cross-section of a grid-screen assembly with the EDM electrode still in place. Figure 18 is an enlarged detail of the same. Note the high length to thickness ratio required by the broach teeth. This feature alone indicates short broach life.

The multiple problems of fabrication, reproducibility and tool life prompted the study to improve broach production methods. The original proposal suggested the EDM method to replace grinding. Exploration of this technique proved negative. High accuracy was required to shape an electrode, maintain the shape, and reposition it each time it was reshaped. In addition, observation of progress of the cut was obscured by the dielectric medium in which the process operated.

A very successful process was developed using the projection grinder and various improvements in fixturing and indexing. By means of a projection grinder, the broach blank is ground to match a chart of the cut imposed on the screen. Skill is still a factor, but just a fraction of the



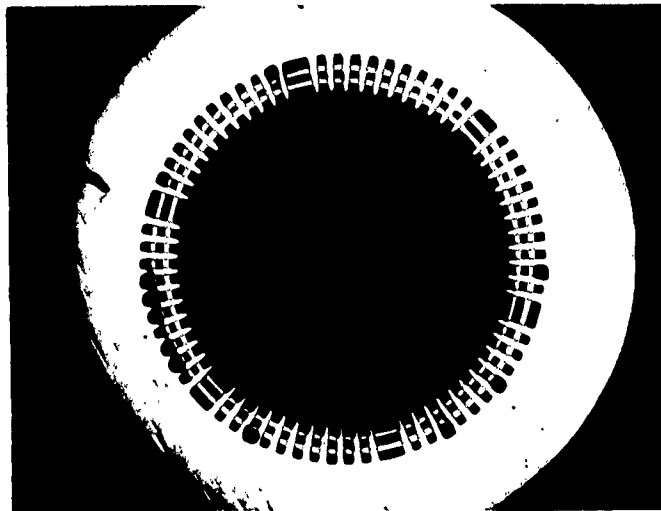


FIGURE 17 - CROSS SECTION OF SCREEN-GRID ASSEMBLY
(EDM electrode still in place)

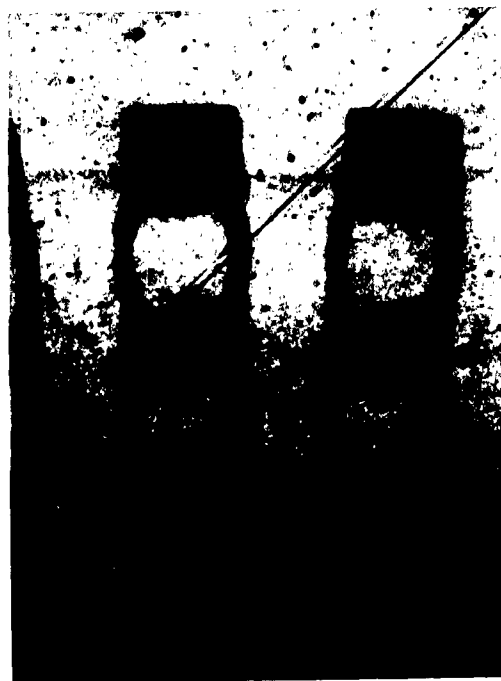


FIGURE 18 - ENLARGED SECTION OF GRID-SCREEN ASSEMBLY
(Portion of above assembly)



former degree required. The machinist observes the progress of his cut, and when finished may inspect the broach on the machine.

In addition to projection broach grinding, other improvements were made which contributed toward longer broach life. The spiral grooved blank eliminated chatter, levelled broaching pressure and reduced tooth breakage. The use of better tool steel decreased broach wear.

G. Grid and Screen Cylinder Revision

The selection of an optimum shape of the grid and screen cylinder was initiated to reduce the time required to cut through the solid metal tops of grid and screen blanks during the EDM slotting operation. Variations in radius and taper were tried, resulting in slight saving of time. However, the improvement did not justify changes in parts making tools.

H. Improve Parts Fabrication Methods

The investigation to improve parts fabrication methods was proposed because the design of Tube Types 7801 and 6884, with their one piece grids, place the burden of tube cost, quality, and producibility on parts manufacturing. Grids and screens are fragile, thinwalled cylindrical shapes dimensioned to close tolerances and requiring high skills for their fabrication.

Automatic machine tools, such as numerical tape control and tracer type lathes offered the best approach to achieve contract objectives. The investigation of these devices included a visit to the Machine Tool Exposition held at Chicago, September, 1960. Inquiries were directed to numerous manufacturers regarding their products and many of these tools were studied for application to the parts described herein. It became apparent that tape controlled and tracer type lathes are not practical for parts run in excess of 50 per month. The requirements of several thousand grids monthly eliminated this field from consideration, a conclusion supported by most of the vendors contacted.



Attention was then directed to conventional high speed turning equipment. The search turned up the Precision Boring Machine, made by Jones & Lamson of Springfield, Vermont. Except for manual loading and unloading, this tool seemed capable of automatically machining the required grid and screen blanks from drawn cups. It is illustrated in Figure 19.

In order to test the capability of the boring machine, several lots of screen blanks were machined at the vendor's plant. From these tests progressive improvements were realized. To obtain greater accuracy, changes were made in machining sequence and minor dimensions. Inside grid diameter machining was tried. Finally 150 screens were machined to evaluate results.

These parts were inspected for barrel ID, wall thickness, perpendicularity and flatness. Time available on the vendor's equipment resulted in the capitalization on all possible improvements. The actual yield was only 30% but on the basis of the process capabilities indicated, there was a sufficiently strong feeling of optimism to warrant recommendation of the Jones & Lamson equipment for parts making.

In the meantime, progress had been made in reducing the skill requirements of the standard method of machining the grids from blanks formed in a series of individual dies. By the use of progressive dies that include coining and pressing stages not only a more accurate blank was obtained, but a reduction in machining was obtained to the extent of two operations.

Concurrently, advances were realized in the two-piece grid and screen concept. This investigation demonstrated the feasibility of the completely drawn, non-machined parts. Tube tests were run with screens made on an experimental tool and matching grids were simulated by carefully re-machining standard parts. Results were successful.



30 JANUARY 1963

FINAL REPORT
DA-36-039-8C 85947

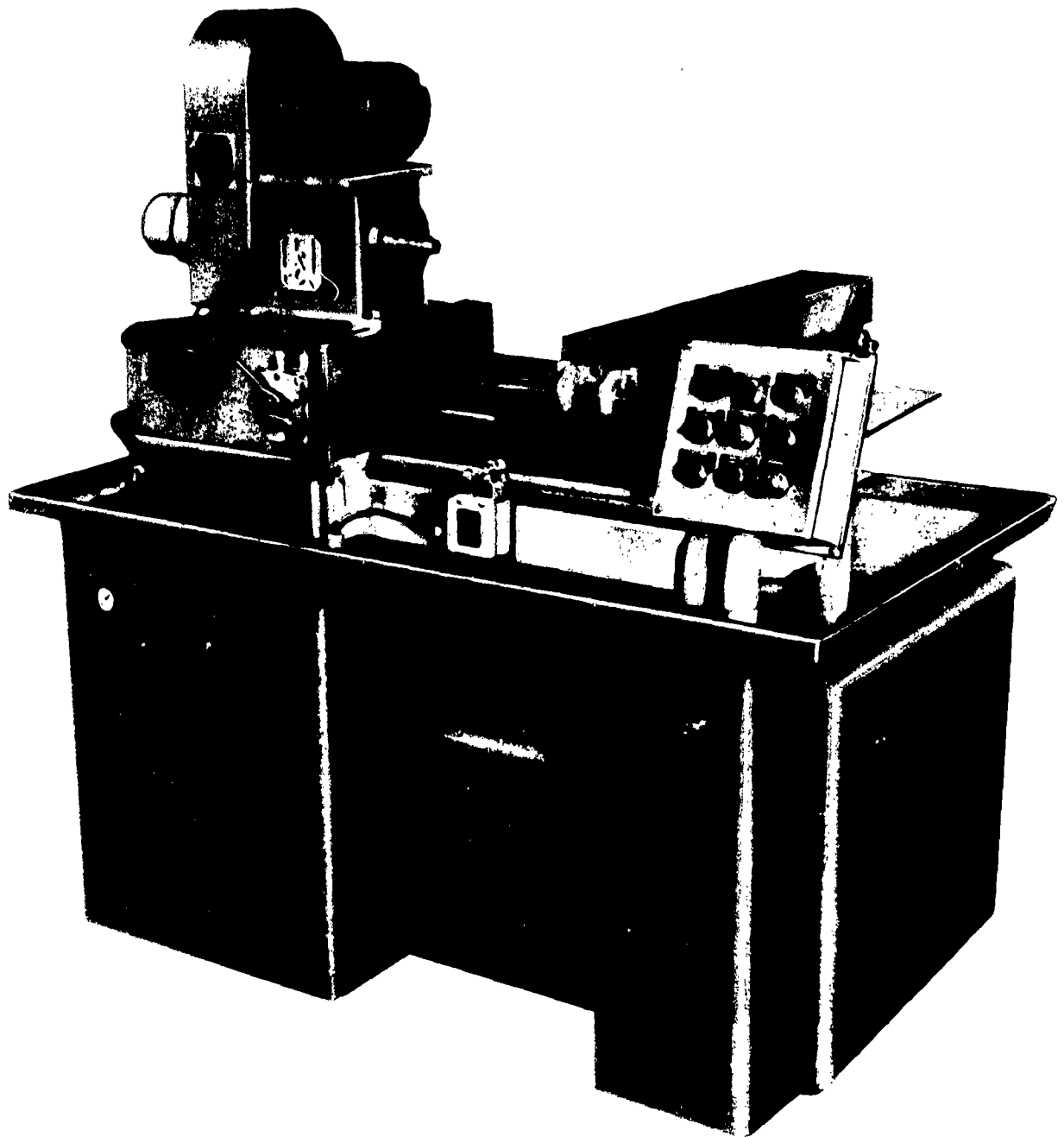


FIGURE 19 - PRECISION BORING MACHINE
(Jones & Lamson Manufacturer)



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

The two-piece, precision drawn, reinforced parts will reduce material cost, eliminate highly critical machining operation and improve producibility. If the 7801 family reaches anticipated production levels, this offers cost reduction and simplification beyond expectations of other methods.

Information acquired regarding the Jones & Lamson boring tool will be applied to cathode machining, where it will be of the greatest value.

A by-product of the improved parts fabrication study was the design of a holding fixture for fragile, thin-wall parts, for which a patent application has been made. This device was designed during the tracer lathe and numerical type control investigations when it was realized that a quick loading, accurate fixture would be needed to utilize the advantages of an automatic or semi-automatic machining system.

I. High Energy Rate Forming of Metal Parts

This work was implemented to explore the possibilities of making precision parts such as grids, screens and cathodes by High Energy Rate Forming (HERF) methods.

At the outset little was known in the field about the forming of the softer metals, copper or nickel, or the feasibility of small precision parts production by this technique.

A search was made of the literature and the following technical sessions were attended:

High Energy Rate Forming Seminar
ASTME - Philadelphia, Pennsylvania
March 29-30, 1961

ASTME Exposition and Conference
New York, New York - Explosive Forming Demonstration
Grumman Aircraft, Bethpage, Long Island, New York
May 23-24, 1961



30 JANUARY 1963

FINAL REPORT
DA-36-039-8C 89747

High Energy Rate Forming Seminar
ASTME - Detroit, Michigan
September 27-28, 1961

High Energy Rate Forming Machine Demonstration
United States Industries - Chicago, Illinois
January 24, 1962

It became evident early in the literature search that in order to obtain operating information, a high energy power source would be required: explosive, capacitor discharge, or gas-ram press. Because of experience in the field of high voltage and capacitor storage equipment, and because this electrical system seemed to offer the most versatility for the tests required, this system was selected.

Communications were exchanged with a number of firms as to the availability of facilities, and for information regarding the adaptations necessary for the planned approach to soft metal, precision parts fabrication. During this period of discussion no indication was given by anyone in the field that the projected effort might be unusually difficult.

When installation was made of the selected energy supply, drawing tests were begun on shallow parts. As the work progressed to the deeper drawing required by grid and screen cylinders it became apparent that the electro-hydraulic technique under investigation would not be feasible. Parts could not be formed from flat blanks because of failure at the intersection of cylinder and flanged portion.

A new approach was made, attempting to expand tubular blanks to form the parts. This was also unsuccessful, apparently because of the axial inertia of the shape and material, resulting in rupture rather than metal flow.

Electromagnetic forming over a mandrel was then tried. Wrinkling and buckling of the thin walled sections could not be controlled, and expectedly, cylinder tops sheared off as cylinders were shrunk on mandrels. The



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

final consideration was parts sizing for precision, which was abandoned because of the elaborate sealing required to close holes designed in the parts.

Sufficient effort was applied to the overall study to establish its non-feasibility. While this program was in progress, parallel efforts were being made in other areas under this contract. It must be acknowledged that HERF techniques cannot hope to compete economically with the high productivity and relatively low cost of progressive die forming.

K. Ultra-High Vacuum Application

The object of this study was to investigate the feasibility of applying ultra-high vacuum (UHV) technology to the evacuation of small metal-ceramic tubes, and, if positive, to supply design information for the development of exhaust equipment.

A "dry" vacuum system was assembled comprising a 15 liter per second Vac-Ion pump; a Vac-Sorb pump; a 300° Centigrade bake-out oven covering the tube, manifold, gauge and Vac-Ion pump; and a small tube oven capable of 600° Centigrade inside the large oven.

Twenty-four tubes were exhausted. Six of these tubes were sent to Mr. L. E. Scharmann at Fort Monmouth as required contractually.

The first several tubes were exhausted and tested to insure integrity. In order to demonstrate economic feasibility it was necessary to reduce process time to that obtained with standard rotary exhaust. The major portion of the initial schedule was consumed in bake-out and bombarding. These were eliminated by changes in the process schedule. The following sequence was used to cut the exhaust schedule to 80 minutes. Figure 20 shows a typical exhaust curve under these conditions:

- (1) Seal tube to manifold and connect power leads.
- (2) Position tube oven (small 600° Centigrade oven).



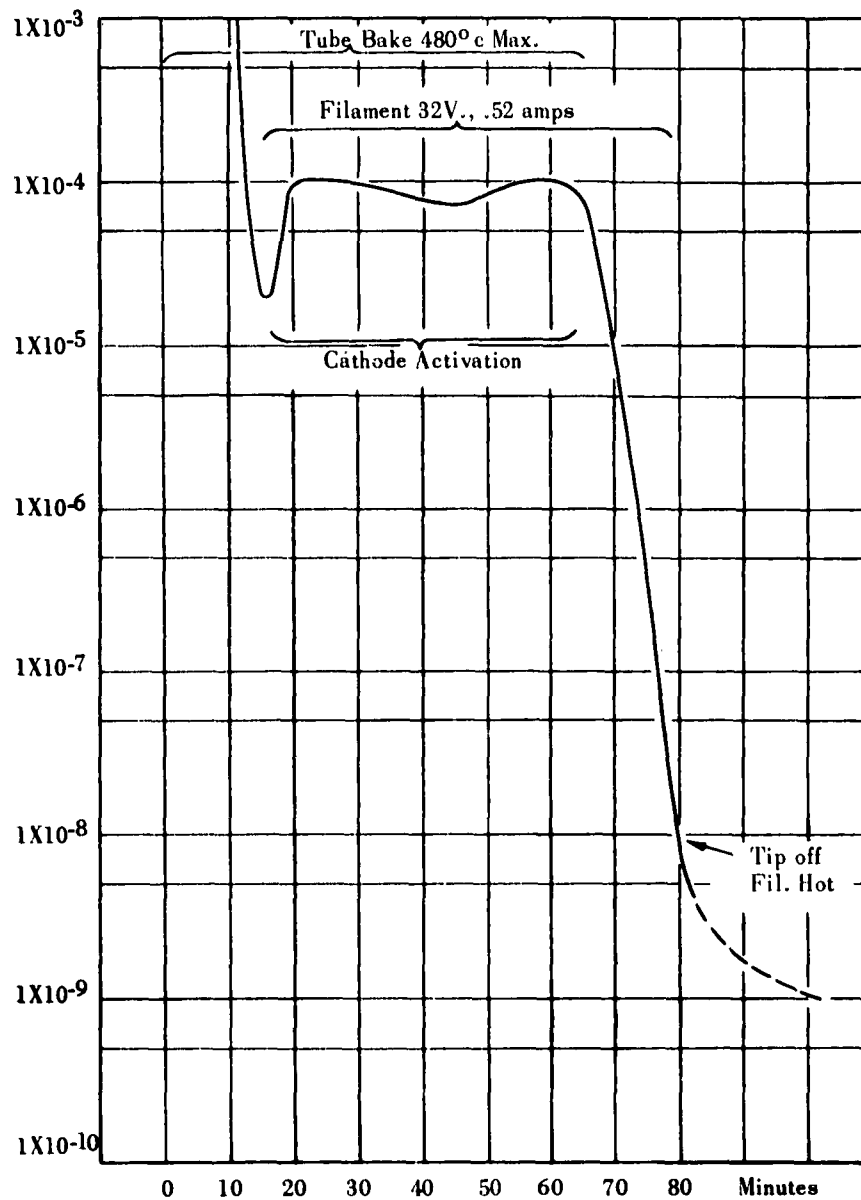


FIGURE 20
TYPICAL 6884 UHV EXHAUST CURVE



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

- (3) Open UHV valve and "start" the Vac-Sorb pump by raising the liquid nitrogen flask.
- (4) Start bake-out to 500° Centigrade anode seal temperature.
- (5) When pressure falls below 3×10^{-2} torr, close valve and start Vac Ion pump.
- (6) When bake-out reaches 430° Centigrade apply filament voltage to break down cathode, limiting gas pressure to 1×10^{-4} torr maximum.
- (7) Terminate bake-out when cathode breakdown is complete.
- (8) Cool tube to room temperature and pinch off with filament hot.

To further reduce the exhaust cycle time, another group of tubes were processed using only the Vac-Sorb pump during bake-out and cathode breakdown. The Vac-Ion pump was then used to lower pressure to pinch-off levels. The exhaust curve for this sequence is in Figure 21. This method shortens exhaust further, because the process speed for cathode breakdown is limited by the Vac-Ion pump's ability to maintain 1×10^{-4} torr. The Vac-Sorb can handle much larger gas volume, but at higher pressures. The Vac-Ion will cease operation when swamped. These tubes were good at initial factory testing.

The improved sequence is as follows:

- (1) Seal tube to manifold and connect power leads.
- (2) Position tube oven (small 600° Centigrade oven).
- (3) Open UHV valve and "start" the Vac-Sorb pump by raising the liquid nitrogen flask.
- (4) Start bake-out to 500° Centigrade anode seal temperature.
- (5) When temperature reaches 430° Centigrade, apply filament power to break down cathode in six 5 minute intervals from 0 to 32 volts.
- (6) Terminate bake-out when cathode breakdown is complete.
- (7) Start Vac-Ion pump and close UHV valve.
- (8) Cool tube to room temperature and pinch off with filaments hot.

Two of the earlier tubes were operated continuously at normal filament voltage for 1500 hours. At 1000 hours, pulse current readings and power output performance tests showed no deterioration. The later tubes, which



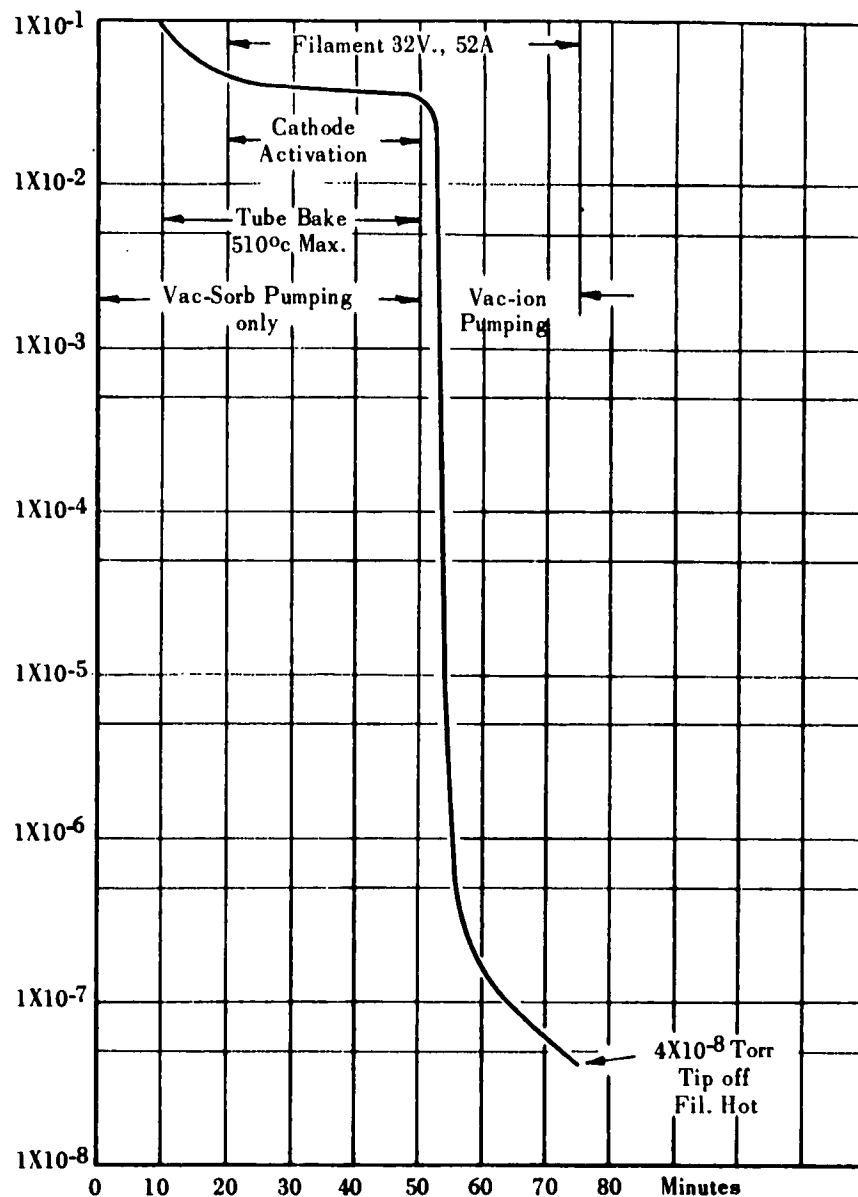


FIGURE 21
TYPICAL UHV EXHAUST CURVE USING LATEST TECHNIQUE



were exhausted at the faster rate, are most significant. Cathode breakdown was accomplished by means of Vac-Sorb pumping alone. The entire schedule was performed in time not exceeding that required for standard processing. These tubes tested satisfactorily and showed no deterioration under the modified life testing time allowed.

Exhaust equipment, stationary, rotary or straight line type can be supplied depending on need. A proposal for a single unit is shown schematically in Figure 22. It will contain a Vac-Sorb pump, automatic UHV valve, and a 15 liter/second Vac-Ion pump. This design will be a stationary unit, or would be incorporated into a multiple position rotary exhaust system as presented in Figure 23, with filament lighting and Vac-Ion electrical needs commutated from wiper tracks. Such a module will be readily removable for servicing, will not require sealex valving, and can be economically assembled.

III. Factory Production

In accordance with contract requirements, manufacturing facilities capable of producing at least 100 tubes per month of the Tube Type 7801 family were established. Personnel have been trained for the required Pilot Run operations.

Following preproduction sample approval of Tube Type 7801, a Pilot Run was made during the month of May, 1962. 137 net good tubes were produced.

Following approval of Tube Type 8384 preproduction sample permission was received to make a Pilot Run in November, 1962. This operation yielded 114 net good tubes.



30 JANUARY 1963

FINAL REPORT
DA-36-039-8C 88947

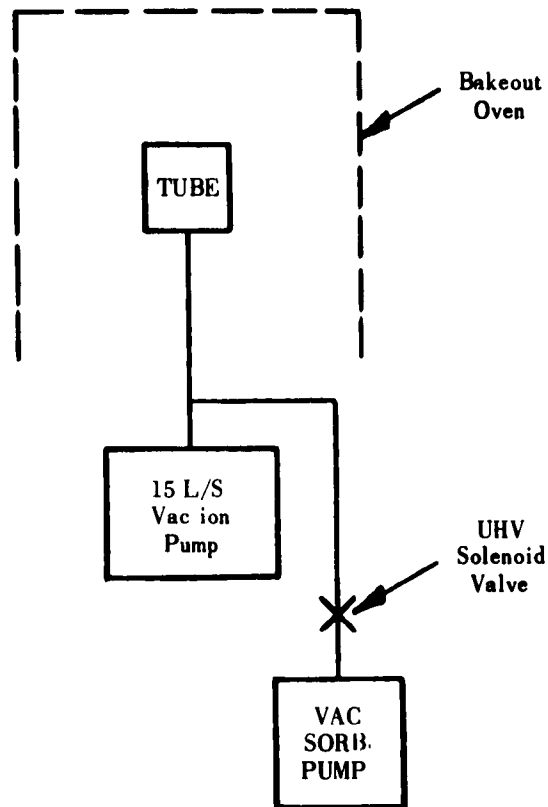


FIGURE 22
PROPOSED PUMPING STATION FOR EXHAUST UNIT



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

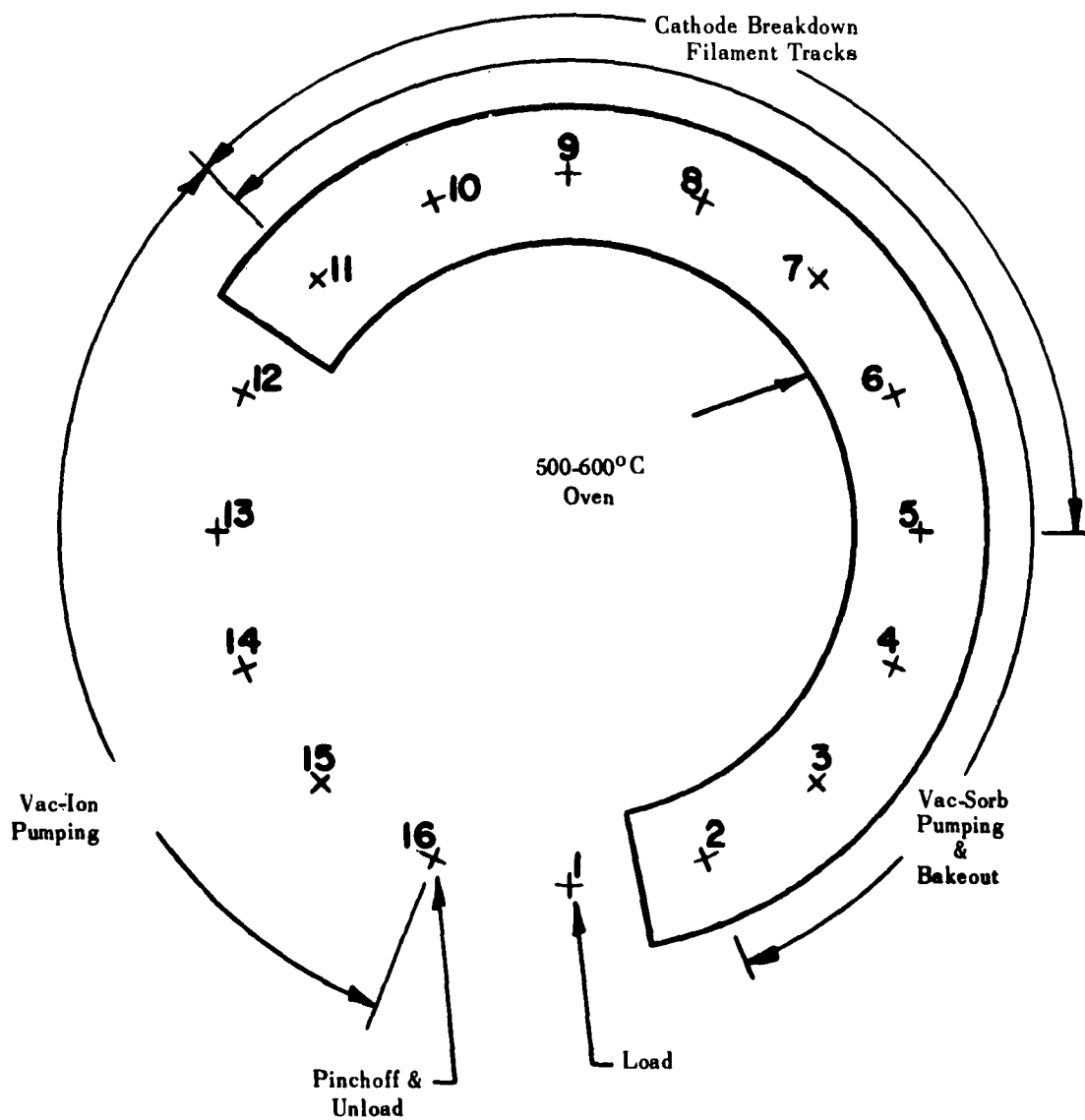


FIGURE 23
SCHEMATIC FOR "DRY" VACUUM ROTARY EXHAUST UNIT



SECTION IV
CONCLUSIONSI. Establish Manufacturing Capability

- A. Complete manufacturing standards are available for the program tube types.
- B. Electrode spacing techniques now in use are capable of mass production techniques.
- C. All facilities and special tools necessary for the minimum production capability were designed, procured and are operable.
- D. A two-cavity life test facility was designed and built for 1,000 megacycle operation and is in use.
- E. In-Plant Design Approval Tests were completed as required for Tube Types 7801 and 8384.

II. Feasibility StudiesA. Brazing Techniques

The Radiamatic Pyrometer was adapted to use with production brazing furnaces, reducing chance of operator error, providing for better control, quality and reproducibility.

B. Improve Heater Design

The ceramic spool heater was developed for type 6884. It offers a more rugged construction, less in-process scrap, greater economy and will prove more reliable in service. A similar heater-cathode assembly is available for the 7801 family.

C. Nickel Thickness Measurement

The Dermatron Gauge was adapted for measuring the thickness of nickel on metallized ceramics, and its calibration to metallurgically sectioned observations was attained.



D. Molybdenum Thickness Measurement

As in the preceding item, the Dermatron Gauge was established as the control device for molybdenum metallizing measurements. A secondary standard was also developed for instrument setup and calibration.

E. Electrical Discharge Machine Stability

The study of EDM equipment determined that long range stability can be achieved by:

1. Addition of a 0.5 μ f mica capacitor across the cutting gap,
2. Substitution of a 6 x 4 vacuum diode for the solid state rectifier in the servocircuit; and
3. Improved heat sink efficiency of the transistors in the servo motor amplifier.

An effective maintenance procedure was also established.

F. Broach Fabrication

Projection grinding was found to be most suitable for broach making. With sufficient experience a good tool can be expected from each start -- within limits of human error. The spiral blank design was demonstrated to insure extended broach life.

G. Grid and Screen Cylinder Revision

It was determined that revising the shape of the parts would reduce cutting time by only a negligible factor.

H. Improve Parts Fabrication Methods

Several successive studies to improve parts making by exotic means obsoleted one another as engineering investigations progressed. The precision boring machine made grid and screen making automatic except for loading and unloading. The use of progressive dies including ironing and coining



stages improved yield and eliminated some of the machining operations. The latest tests indicated that precision drawn screens and grids can eliminate all machining operations. As a result of the experience with grid and screen fabrication, the precision boring machine techniques have been successfully applied to cathode machining.

I. High Energy Rate Forming of Metal Parts

Electro-hydraulic forming of drawn parts, expanding of tubular blanks, electromagnetic forming to mandrel shapes, and finally parts sizing were all pursued without spectacular success. It became apparent that High-Energy-Rate-forming of small, soft metal parts is not economically feasible when compared to progressive die forming by conventional presses.

K. Ultra-High Vacuum Application

Tubes were exhausted by "dry" pumping methods to several orders of magnitude better pressure than is attained with standard conventional facilities. Tubes similar to tube type 6884 can be exhausted in the same length of time as the standard schedule, and it is estimated that facilities can be procured at lower capital expenditures.

III. Factory Production

Manufacturing facilities capable of producing at least 100 tubes per month, either 7801 or 8384, are available as was demonstrated by the Pilot Runs of May and November, 1962.



SECTION V

IDENTIFICATION OF TECHNICIANS

The following engineering personnel contributed to the effort reported herein, during the program. Their biographies are submitted, herewith.

<u>Engineering Personnel</u>	<u>Hours Applied</u>
Paul S. Augustine	29
P. G. Bedrosian	367
Morris Berg	26
Henry George Booske	688
Frederick W. Brill	1748
Jean Bertolet Bucher	117
Ralph R. Calabrese	163
Reno R. Carbonetta, Jr.	1250
L. J. Conklin	44
Edward J. Cooper	236
Jack Herbert Davis	212
Karl Dreyer	2205
George E. Eiwen	110
Robert W. Etter	65
Gardner L. Fassett, Jr.	862
Jules M. Forman	42
John W. Gaylord	35
Carl Hart	70
William G. Henderson	330
Murray R. Horton	3895
W. Philip Keller	726
Fred P. Koeng	871
Lawrence J. Levengood	138
Paul M. Long	2374
William J. Maddox	540
Daniel N. Myers	635



30 JANUARY 1943

FINAL REPORT
DA-36-039-SC 85947

Engineering Personnel

Hours Applied

Dorothy J. Neal	262
James G. Ottos	350
Fred W. Peterson	96
Robert R. Reidenbach	339
Marinus Van Renssen	1219



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

Paul S. Augustine

Mr. Augustine received two degrees from Pennsylvania State University. He was graduated with an Associate degree in Electrical Technology and a Bachelor's degree in Electrical Engineering in 1955 and 1959, respectively.

Mr. Augustine joined RCA Lancaster in June of 1959 and worked on various assignments as a Specialized Engineering Trainee. In November of 1959 he joined the Power Tube Engineering Design group as a Design and Development Engineer. Since joining the group, he has worked on the development and fabrication of the RCA Developmental A-2582 and A-2582A.

He is a member of Eta Kappa Nu.



P. G. Bedrosian

Mr. Bedrosian received his B.S. degree in Electrical Engineering from the University of New Hampshire in June, 1953. He joined RCA in 1953 as a Specialized Trainee in the Color Kinescope Production Development group of the Lancaster plant.

He took a leave of absence from November, 1953 to January, 1956 to serve in the Armed Forces. He served as a Medical Equipment Repairman at the Tokyo, Japan Army Hospital during the major part of his tour of duty.

On his return to RCA, he joined the Large Power Tube Manufacturing Activity working as a Production Engineer. He was promoted to Junior Engineer and later to Associate Engineer while working with this group. He transferred to the Specifications Engineering group of the Life Test and Data Laboratory in 1958 where he was responsible for the establishment of Technical Data and Test Specifications. In 1961 he was promoted to his present title of Engineer and was given the responsibility of establishing proposed military specifications, preparing data, tests, and reports necessary for Qualification Approval.

Mr. Bedrosian presently serves on Military Ad Hoc committees and is a member of a JEDEC committee. He has been a member of the Institute of Radio Engineers since 1949. He also holds an Amateur Radio License.



Morris Berg

Dr. Berg received the Bachelor of Science degree in ceramic engineering from Ohio State University in 1942, and the Doctor of Science from Massachusetts Institute of Technology in the same field in 1953. He has been at RCA since 1954.

Before joining RCA as Leader of the Ceramic and Glass staff of the Chemical and Physical Laboratory he worked a year with the Bureau of Mines as a Project Ceramic Engineer; was a Research Chemist at M. I. T. for four years; and spent five years with AC Spark Plug Division of General Motors Corporation. Dr. Berg served in the Navy 1944-46 as an Ordnance and Bomb Disposal Officer.

He has worked extensively in the field of ceramic-to-metal sealing and in the use of ceramic coatings to protect metals from corrosion at high temperature. He was responsible for the development of the highly reliable ceramic-to-metal seals used at RCA, and has assumed a leading role in the improvement of commercial ceramic quality through the ASTM.

Dr. Berg is a member of Tau Beta Pi, Sigma Xi, the American Ceramic Society, for Metals.



Henry George Booske

Mr. Booske was graduated from Drexel Institute of Technology in 1950 with a B. S. in Mechanical Engineering.

During World War II he attended the U. S. Navy Quartermaster School, Newport, R. I. and served overseas with the Pacific Fleet.

In 1956 he joined the Radio Corporation of America as an Associate Engineer at the Lancaster Plant, Electron Tube Division, Advanced Equipment Development And Engineering. Since that time he has been associated with this group working on various electron tube equipment designs and development.

He is an associate member of the American Society of Mechanical Engineers.



Frederick W. Brill

Frederick W. Brill received a B.S. degree in Chemistry from Western Maryland College.

He joined the Radio Corporation of America, Equipment Development and Engineering in 1959 with the title of Associate Engineer. He is now engaged in studies of electroplating processes including electrolytic machining. He has also studied disintegration effects on certain organic compounds under the influence of various chemicals.

Mr. Brill has several patents in various stages of application from places of his previous employment including: compatible 3-D television system, a transistorized metronome, a droplet detector, and a method of applying aluminum film evenly to the screen of large cathode ray tubes.

Prior to joining RCA, his previous work experience was in cathode ray tube manufacture, semiconductor manufacture, measuring and controlling instrument design and chemical manufacturing.



30 JANUARY 1963

FINAL REPORT
DA-36-039-SC 85947

Jean Bertolet Bucher

Jean Bertolet Bucher graduated from Waynesburg College, Pennsylvania in 1953 with a Bachelor of Science Degree in Physics.

From January 1954 to December 1955 he served in the U. S. Army. After completing Field Radio Repair School, he served with the 123rd Signal Company in the Canal Zone as an Electronic Equipment Repairman.

He joined the Radio Corporation of America in 1953 as a Specialized Trainee. Following his military service he completed the training program and was assigned as a Junior Engineer in Camera, Oscillograph, and Storage Tube Engineering in 1956. He was advanced to Associate Engineer in 1957 and assumed his present position with Equipment Development and Engineering in 1960.

He has worked on product design of projection kinescopes and the one and one-half inch vidicon. He also developed test procedures and equipment for laboratory testing of one-half inch, one inch and one and one-half inch vidicons and special equipment for advanced development experimentation.

He was co-inventor of an improved Focus and Deflection Device for use with Vidicon Camera Tubes.



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

30 JANUARY 1963

FINAL REPORT
DA-36-039-8C 88947

Ralph R. Calabrese

Following a four year enlistment in the U. S. Navy, Mr. Calabrese entered Massachusetts Institute of Technology where he studied electrical engineering. He left school at the end of his third year and was employed by RCA as a laboratory technician. After one year in this capacity, he obtained a leave of absence and returned to M. I. T. to complete his education, graduating in 1959 with the Bachelor of Science degree in Electrical Engineering.

On his return to RCA, he was assigned to Super Power Tube as a Junior Engineer, Product Development, where he worked on a vacuum system for testing the electron optics of a new tube concept. During construction of the A. E. C. sponsored C-Stellarator vacuum system, Mr. Calabrese was transferred to this activity where he was in charge of the group that tested components before inclusion into the vacuum system.

Since August, 1961, he has been in Small Power Design, developing variations of type 7801.



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

Reno R. Carbonetta, Jr.

Mr. Carbonetta graduated from Franklin and Marshall College in 1960 with the Bachelor of Science degree in physics.

He served six months in the U. S. Army prior to joining RCA in June 1961. After finishing his basic and technical training he was assigned to Fort Sheridan, Illinois as a Post Electrician.

Between graduation and military service he worked as draftsman for a construction engineering firm.

Mr. Carbonetta is a member of the American Institute of Physics. He came to work at RCA as a Manufacturing Engineer, Junior.



90 JANUARY 1963

FINAL REPORT
DA-36-039-8C 88947

L. J. Conklin

Mr. Conklin has been in the employ of RCA since his graduation from Alfred University in 1950. He holds a Bachelor of Science degree in Glass Technology.

He was assigned, as Engineer, to the development of metal bulbs for kinescopes; the development of glass two-piece bulbs for Color kinescopes; and tube processing problems at sealing and exhaust.

From 1960 to the present, he worked in the Chemical and Physical Laboratory, Advanced Development Group, on application of radiotracer techniques to tube processing, and cathode processing studies.

He is the recipient of an RCA Merit Award.



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

30 JANUARY 1963

FINAL REPORT
DA-36-039-SC 89947

Edward J. Cooper

Mr. Cooper received his Bachelor's degree in Electrical Engineering from Pennsylvania State University in 1956.

He joined RCA in June of 1956 and worked on various assignments as a Specialized Engineering Trainee. In November of 1956 he joined the Small Power & Gas Tube activity as an engineer where he worked on the development and fabrication of the A-2547A, and more recently, type A2582A.

He is a member of the IRE.



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

Jack Herbert Davis

Jack H. Davis attended Merchant-Venturers Technical College, Bristol England for two years including studies in mathematics, economics and business administration.

He served with the Royal Air Force from January 1941 to May 1946. Received specialized training in aircraft engine design, construction and maintenance, mechanics and hydraulics.

Served as Engineer in project engineering departments of various firms from 1946 until joining the Radio Corporation of America in 1957 as an Associate Engineer, Equipment Development and Engineering.

Since being employed by RCA majority of work has been in the design of vacuum processing equipment.



30 JANUARY 1963

FINAL REPORT
DA-36-039-SC 83947

Karl Dreyer

Mr. Dreyer received his BS from the Cooper Union in 1929 and the graduate degree of Chemical Engineer in 1934. He joined RCA at Harrison, New Jersey, as a Receiving Tube Development Engineer in 1929. From 1934 until 1944, he continued in Power Tube engineering. During 1944 and 1945 he was assigned to the International Division as a Vacuum Tube Specialist. In 1946 he transferred to the Lancaster Plant as Process Quality Control Manager. Most recently he was Senior Engineer in the Vacuum Engineering section which constructed the C-Stellarator under an A. E. C. contract.

He is a senior member of the IRE and belongs to the American Vacuum Society.



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

30 JANUARY 1963

FINAL REPORT
DA-36-039-SC 88947

George E. Eiwen

Mr. Eiwen received his B. S. and M. S. in Glass Technology from Alfred University in 1950 and 1951 respectively.

He served in the Pacific Theater with the U. S. Navy for two and one-half years during World War II.

From 1951 to 1954 he was an engineer in the Tube Development Shop where he worked on glass-to-metal seal process development. In 1955 he was made an acting group leader in the Color Tube Development Shop. During 1955-1957 he was active in the development and production of Color Kinescopes. In 1960 he joined the ceramic group of the Chemical and Physical Laboratory, as a Design and Development Engineer. More recently he has been active in the development of a thin film Image Orthicon Target and fiber optic seal techniques.



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

30 JANUARY 1963

FINAL REPORT
DA-36-039-SC 85947

Robert W. Etter

Mr. Etter received the Bachelor of Science degree in Chemistry from Lebanon Valley College in 1935, the Bachelor of Divinity at Bonebrake Theological Seminary, 1945, and is currently pursuing the Master of Science degree at Franklin and Marshall College after hours.

He has a wide background in chemical processing, particularly with respect to electroplating and plastics development. Before joining RCA in 1952, he had acquired research experience with Hamilton Watch Company and General Motors from 1935 through 1944.

He is a member of Phi Beta Kappa and The American Electroplaters Society.

Mr. Etter is the author of several publications and holds four patents.



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

Gardner L. Fassett, Jr.

Mr. Fassett attended the New Bedford Textile Institute, graduating with the B. S. in Mechanical Engineering in 1953.

Before going to college he served three years in the U. S. Navy as a Rated Draftsman in Naval Air Service. He took part in the design, installation and testing of transport aircraft equipment.

Following two and a half years in the textile machinery industry he came to work at RCA, January 1956, as an associate engineer in Equipment Development and Engineering.

He has been active in high vacuum technology, electrical discharge machining and reduction rolling. He holds a patent for a sealing device for color picture tubes, which contributed to the conversion from metal to glass envelopes.



Jules M. Forman

Mr. Forman graduated from Stevens Institute of Technology in 1940 with a degree in Mechanical Engineering. While doing graduate work at Stevens in mathematics, electronics and metallurgy from 1940 to 1942, he also served as a Teaching Fellow in machine design, 1940-41.

He joined RCA in 1941 where he was employed in the electrical design section of Equipment Development, later transferring to the Life Test and Data Laboratory. During this period he also studied ultra-high frequency techniques at Newark College of Engineering.

In 1951 Mr. Forman became Group Leader of Special Equipment Engineering. His activity was expanded in 1956 to include environmental evaluation of new and improved tube ruggedization developments.

He is the author of numerous engineering memoranda and laboratory reports on circuitry pertaining to electron tubes, and has published technical papers in this field. He also has several patent disclosures pending.

Mr. Forman is a licensed professional electrical engineer.



John W. Gaylord

Mr. Gaylord received his BS in Physics from the Massachusetts Institute of Technology in 1952 and his MS in Physics from Franklin and Marshall College in 1958. During his undergraduate course of study he worked in the Radiation Laboratory at M. I. T. He joined RCA in 1952 as a specialized engineering trainee. In this capacity he worked on transistorized telephone systems for Defense Electronic Products at Camden, J. W., on germanium crystal growth at the Chemical and Physical Laboratory at Harrison, N. J., on optical diffusion systems for black and white television at Commercial Electronic Products at Camden, N. J., and on Gas Tube Design at Lancaster, Pa.

From 1953 to 1959 he was an engineer in the Small Power Tube Design Group. His work included the design and development of small power tube types for UHF and VHF use, such as the 5894, 7094 and a double ended coaxial tube type. In 1959 he was made Acting Group Leader of Small Power Tube Design group. He is a member of the IRE, American Metals Society, a holder of an Amateur License, and a member of Sigma Pi Sigma Honorary Physics Society. He holds one patent.



Carl Hart

Mr. Hart studied business administration at the Wharton School, University of Pennsylvania before attending the University of Cincinnati for his degree in Electrical Engineering. He received the B. S. E. E. with a major in public utility work, and an advanced degree in Commercial Engineering two years later.

He joined RCA in 1943, working in the capacity of Engineer, Machine Design. In 1955 he was advanced to Equipment Development Engineer.

Mr. Hart is a registered Electrical Engineer, and a member of the National Society of Professional Engineers.



30 JANUARY 1963

FINAL REPORT
DA-36-039-SC 85947

William G. Henderson

William Henderson received his BSEE from the University of Arkansas and started work with the Radio Corporation of America in 1949 under the Specialized Trainee Program.

In 1950, he joined the Mechanical Engineering Department of Equipment Development and Engineering, Lancaster, where he has specialized in design of electron tube exhaust machines and other high-vacuum equipment.

Since 1958, he has been actively engaged in the design of the Ultra-High Vacuum System for the Model C-Stellarator. This system, for the thermonuclear machine, has achieved the lowest pressure ever attained in such a large vacuum vessel.

Mr. Henderson is a member of the Tau Beta Pi and AIEE and is a Registered Professional Engineer of the State of Pennsylvania.



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

Murray R. Horton

Mr. Horton was graduated from Pennsylvania State University in 1951 where he received a BS degree in Electrical Engineering.

He served in the U. S. Navy for one and one-half years during World War II.

Following varied tube engineering experience on Receiving Tube and close-spaced metal-ceramic tubes, he joined the Radio Corporation of America in 1956 as an Associate Engineer.

During his employment at RCA, he has served as Manufacturing Engineer in the Small and Medium Power Tube Departments. Successively, he has had Manufacturing Engineering responsibilities for practically all major product lines in those departments.



30 JANUARY 1963

FINAL REPORT
DA-36-039-SC 88947

W. Philip Keller

W. Philip Keller attended Hershey Junior College and Juniata College, for two years each, majoring in Chemistry. He also studied at the Franklin and Marshall College, Evening Graduate School for one year.

He joined the Radio Corporation of America, Lancaster, in 1946, as a Manufacturing Development Engineer in the Kinescope Factory. In 1950 he was transferred to the newly-formed Color Tube Factory where he remained until 1954 when he joined the Advanced Processes Section of Equipment Development and Engineering.

Mr. Keller has specialized in Kinescope Bulb Processing and has developed Kinescope and Oscilloscope Screening and Filming Methods, a Phosphor Plate Alignment Method, and a Slurry Salvage Technique for Color Tube Screening.

He is a member of the American Chemical Society. He received RCA's Golden Achievement Citation in 1955 for meritorious effort.



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

Fred P. Koeng

Fred P. Koeng was graduated from Columbia (Lancaster County) High School in 1934 and completed the I. C. S. courses in Radio Operating, and Electrical Engineering.

He served in the Pennsylvania National Guard in the Signal Corp for three years.

Following varied work experience including two years service with a civilian airport in charge of Aircraft and Radio Station Maintenance, he joined the Radio Corporation of America in 1942 as a Test Set Maintenance Technician. In 1943 he transferred to Equipment Development and Engineering as a Detail Draftsman, and was advanced to Electrical Design Draftsman. In 1950, following additional study and experience, he was promoted to Electrical Engineer.

He developed and wrote an RCA Engineering Memorandum on a new accurate method of Measuring Aluminum Film Thickness on Color Picture Tube Face Panels. He has been an active radio amateur for the past 26 years during which time he designed and built all of his own equipment for amateur radio use.



Lawrence J. Levengood

Mr. Levengood graduated from Villanova University in 1959 with a Bachelor of Electrical Engineering degree. For the past two years he has been taking graduate courses at the Moore School of Electrical Engineering of the University of Pennsylvania, where he hopes to obtain his Masters degree.

Since joining the Special Equipment Engineering group of RCA's Lancaster plant in 1959, he has been engaged in the design of electronic testing equipment and circuits for power tubes, photocells and electro-luminescent devices.

Mr. Levengood is a member of the Institute of Radio Engineers and an associate member of the American Institute of Electrical Engineers.



Paul M. Long

Paul M. Long was graduated from Lancaster High School in 1933 and later took undergraduate courses in the Pennsylvania State College Extension School.

He joined Radio Corporation of American in 1943 as a Toolmaker. In 1947 Mr. Long was transferred to Equipment Development and Engineering as a Mechanical Designer from which he was later promoted to Associate Engineer.

He is now assigned to the Advanced Processes and Development group of Equipment Development and Engineering as a Mechanical Engineer.

In 1955 Mr. Long received one of the RCA's Golden Achievement Year Awards for his part in the development of the Color Kinescope Screen Process Conveyor.



William J. Maddox

William J. Maddox was graduated from Purdue University in 1950 where he received a B.S. degree in Electrical Engineering. At Purdue he was elected to Eta Kappa Nu, an Electrical Engineering Honorary Society. His major courses of study centered around communications.

From 1942 to 1945 he served with the U.S. Navy as a radio technician having graduated from the U.S. Navy Radio Material School at Treasure Island, San Francisco.

He joined RCA in 1950 as an Engineering Trainee in the Equipment Development and Engineering Department. Upon completion of his training period, he assisted in the design of several Electron Tube Testing and Aging Equipments including pulse-type aging equipment for Hydrogen Thyratrons and also Oscilloscope Test Equipment. He worked on the design of the first Vidicon Test Set at RCA.

From 1954 to 1959 he was Manager of the Electrical Drafting Department in Equipment Development and Engineering. From 1959 until the present time he has been doing electrical engineering design work and has contributed to the design of Semi-Conductor Rectifier Test Equipment. Other specialties include design experience in oven and furnace equipment and controlled-atmosphere types of furnaces.



30 JANUARY 1963

FINAL REPORT
DA-36-039-SC 89947

Daniel N. Myers

Daniel N. Myers was graduated in 1948 from the Pennsylvania State University, with a B.S. degree in his major of Electrical Engineering.

During World War II as a member of the Army Air Corps, he was graduated from Cadet School, and served overseas as a fighter pilot, 1st Lt., with the 8th Air Force.

He joined RCA in 1948 as an Engineer in the Kinescope Activity, then later the Color Picture Tube Activity. He transferred to the Equipment Development and Engineering in 1951 as Engineer and has been employed in this capacity to date. During this portion of his employment he did original design work on Power Supplies, Instrumentation Pulse Circuits, Control Circuits, and Optics. This work was done incident to the design of Color Picture Tube Test Equipment, a Recording Spectroradiometer, Photo Tube and Pickup Tube Test Equipment, Silicon Diode Test and Life Test Equipment, and, Electrical Discharge Machining.

Mr. Myers is a registered professional Engineer in the Commonwealth of Pennsylvania.



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

Dorothy J. Neal

Miss Neal joined RCA in 1943. She was sent to Purdue University for one year as an RCA Cadette, to be trained as a technician. Upon her return she was assigned to Power Tube Design as an engineering aide. After four years of this work she returned to Purdue and obtained the Bachelor of Science degree in Physics.

Returning to RCA she was appointed Laboratory Assistant in Metallurgy. Miss Neal worked for five years as Laboratory Assistant, and for the past six years as Junior Engineer.

Her experience includes investigations into the physical properties of metals, such as physical testing, metallographic examination, heat treating of electron tube materials, and ceramic technology.



James G. Ottos

Mr. Ottos received his BS in Electrical Engineering from the University of Buffalo in 1950. He joined RCA as a specialized trainee in 1951. At the completion of the training program, he was assigned to the Special Equipment Engineering Group of the Life Test and Data Laboratory.

Since 1952, he has been responsible for designing numerous complex electro-mechanical test sets, life test equipments, and special applications of electronic circuitry for small and large power, cathode ray, color, photo and image, and display storage electron tube types.

Mr. Ottos attended evening classes at Franklin and Marshall College from 1951 to 1956. He is currently working on his thesis, and upon its successful completion, he will be awarded his MS in Physics. He is also a member of Sigma Pi Sigma, the Physics Honor Society.



Fred W. Peterson

Mr. Peterson received his Bachelor of Science Degree in Electrical Engineering from the University of Arizona in 1949.

He joined RCA at Lancaster in 1949 and worked on various assignments as a Specialized Engineering Trainee. In 1959 he was assigned to the Power Tube Development group in the capacity of a Design & Development Engineer. From 1950 to 1954, Mr. Peterson was responsible for the design of UHF circuitry used in evaluating the RCA 6161, 6181, and 6448 power tubes. In 1954 he was assigned to Power Tube Design group as a design engineer where he worked on the RCA 6816, 6884 and the developmental type A-2547A. In 1956 Mr. Peterson was appointed to his present position of Engineering Leader, for the Medium Power Tube Design group.

Mr. Peterson is a member of Tau Beta Pi, Phi Kappa Phi, Pi Mu Epsilon, and Sigma Pi Sigma.

He holds one U.S. Patent in the field of electronics.



30 JANUARY 1963

FINAL REPORT
DA-36-039-SC 83947

Robert R. Reidenbach

Mr. Reidenbach was graduated from Lancaster Boys High School, where he had taken the Industrial Education course.

He came to work for RCA in 1949 as Mechanical Draftsman-Designer and was promoted in 1952 to Associate Engineer, Equipment Development and Engineering, the position he now holds. Prior to coming here he worked as liaison engineer between electrical and hydraulic groups for a major airplane manufacturer.

He has been associated with the development of mass production techniques, introducing many innovations to the manufacture of color tubes and tooling for the 1/2-inch Vidicon.

In 1955 Mr. Reidenbach was awarded RCA's Golden Achievement Citation for his accomplishments beyond job requirements.



INDUSTRIAL TUBE PRODUCTS A DEPARTMENT OF THE ELECTRON TUBE DIVISION - RADIO CORPORATION OF AMERICA

Marinus Van Renssen

Mr. Van Renssen was graduated in Mechanical Engineering in July 7, 1951 from the Industrial Engineering College at Eindhoven, The Netherlands.

He joined the Radio Corporation of America on October 3, 1955 as an Associate Engineer, Equipment Development. In 1957 he advanced to his present position of Engineer, Equipment Development.

During his employment at RCA he has been engaged in the design and development of production and processing equipment for electron tubes including adapting optical comparators to simultaneously line-up and braze power tube assemblies, designing semi-automatic welding machines, graphite coating machines and vacuum processing equipment. During 1957 he designed and developed production facilities for the 6861 Traveling Wave Tube Program. He was the author of the article "A Non Uniform Indexing Device" which was published in "Machine Design" issue of November 13, 1958.

